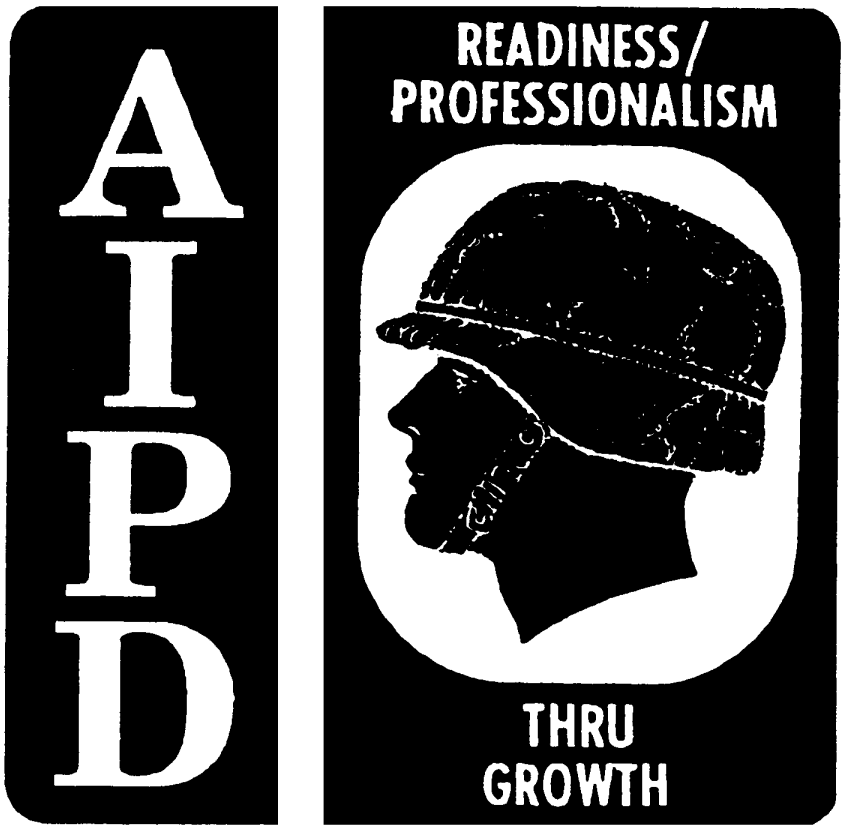
SUBCOURSE
OD1620

EDITION
7

PRINCIPLES OF GASOLINE AND DIESEL FUEL SYSTEMS



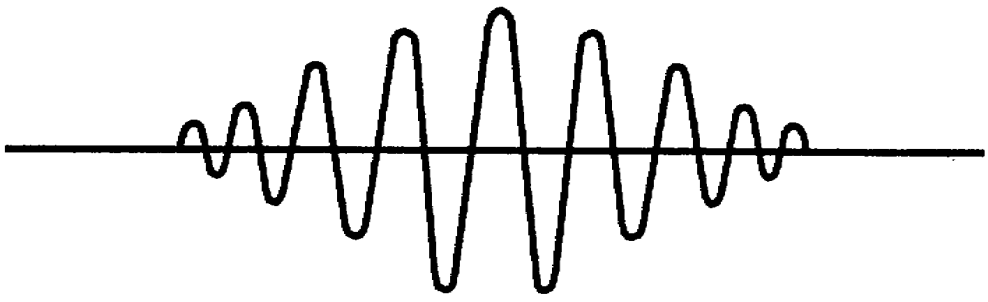
THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

Notice to Students

Use the Ordnance Training Division website,
http://www.cascom.army.mil/ordnance/,
to submit your questions, comments, and suggestions
regarding Ordnance and Missile & Munitions
subcourse content.

If you have access to a computer with Internet capability and can receive e-mail, we recommend that you use this means to communicate with our subject matter experts. Even if you're not able to receive e-mail, we encourage you to submit content inquiries electronically. Simply include a commercial or DSN phone number and/or address on the form provided. Also, be sure to check the Frequently Asked Questions file at the site before posting your inquiry.



US ARMY BRADLEY FIGHTING VEHICLE
SYSTEMS MECHANIC

MOS/SKILL LEVEL: 63T30

PRINCIPLES OF GASOLINE AND DIESEL FUEL SYSTEMS

SUBCOURSE NO. OD1620

US Army Correspondence
Course Program

6 Credit Hours

GENERAL

The purpose of this subcourse is to introduce the characteristics of gasoline and diesel fuel systems. This discussion will include a description of the principles, construction, and function of these two systems.

Six credit hours are awarded for successful completion of this subcourse which consists of two lessons divided into tasks as follows:

Lesson 1: FUNCTION AND CONSTRUCTION OF GASOLINE FUEL SYSTEMS

TASK 1: Describe the characteristics of gasoline.

TASK 2: Describe the principles, construction, and function of gasoline fuel systems.

Lesson 2: FUNCTION AND CONSTRUCTION OF DIESEL FUEL SYSTEMS

TASK 1: Describe the characteristics of diesel fuel.

TASK 2: Describe the principles, construction, and function of diesel fuel systems.

TABLE OF CONTENTS

Section	Page
TITLE	i
TABLE OF CONTENTS	ii
ADMINISTRATIVE INSTRUCTIONS	iii
GRADING AND CERTIFICATION INSTRUCTIONS	iii
Lesson 1: FUNCTION AND CONSTRUCTION OF GASOLINE FUEL SYSTEMS	1
Task 1: Describe the characteristics of gasoline	1
Task 2: Describe the principles, construction, and function of gasoline fuel systems	7
Practical Exercise 1	53
Answers to Practical Exercise 1	56
Lesson 2: FUNCTION AND CONSTRUCTION OF DIESEL FUEL SYSTEMS	58
TASK 1: Describe the characteristics of diesel fuel	58
TASK 2: Describe the principles, construction, and function of diesel fuel systems	63
Practical Exercise 2	113
Answers to Practical Exercise 2	116
REFERENCES	118

THIS PAGE INTENTIONALLY LEFT BLANK

STUDENT NOTES

***** IMPORTANT NOTICE *****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

LESSON 1

FUNCTION AND CONSTRUCTION OF GASOLINE FUEL SYSTEMS

TASK 1. Describe the characteristics of gasoline.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

Petroleum is the most common source of fuel for modern internal combustion engines. It contains two important elements: carbon and hydrogen. These elements are mixed in proportions such that allow them to burn freely in air and liberate heat energy. Petroleum contains a tremendous amount of potential energy. In comparison to dynamite, a gallon of gasoline has six times as much potential energy. Gasoline is the most widely used petroleum-based engine fuel.

Two advantages of the use of gasoline are a better rate of burning and easy vaporization to give quick starting in cold weather. The major characteristics of gasoline that affect engine operation are volatility, purity, and antiknock quality (octane rating). In this lesson, the function and construction of gasoline fuel systems will be discussed. This first task will center on the specific characteristics of gasoline.

2. Volatility in Gasoline

Volatility, as applied to gasoline, is its tendency to change from liquid to vapor at any given temperature. The volatility of gasoline affects ease of starting, length of warmup period, and engine performance during normal operation. The rate of vaporization increases as the temperature increases and as pressure decreases. The volatility of gasoline must be regulated carefully so that it is volatile enough to provide acceptable cold weather starting, yet not be so volatile that it is subject to vapor lock during normal operation. Refiners introduce additives to gasoline to control volatility according to regional climates and seasons.

a. *Starting Ability.* To provide satisfactory cold weather performance and starting, the choke system causes a very rich mixture to be delivered to the engine. Gasoline that is not volatile enough will cause excessive amounts of raw unvaporized fuel to be introduced to the combustion chambers. Because unvaporized fuel does not burn, it is wasted. This reduces fuel economy and causes a condition known as crankcase dilution.

b. *Crankcase Dilution.* Crankcase dilution occurs when the fuel that is not vaporized leaks past the piston rings and seeps into the crankcase. The unvaporized fuel then dilutes the engine oil, reducing its lubricating qualities.

A certain amount of crankcase dilution occurs in all engines during warmup. It is not considered harmful in normal quantities because it vaporizes out of the oil as the engine warms-up. The vapors are then purged by the crankcase ventilation system.

c. *Vapor Lock.* Vapor lock is one of the difficulties experienced in hot weather when using highly volatile fuels. When fuel has a tendency to vaporize at normal atmospheric temperature, it may under higher temperature form so much vapor in the fuel line that the action of the fuel pump will cause a pulsation of the fuel vapor rather than normal fuel flow. Heat insulating materials or baffles are often placed between the exhaust pipe and fuel line to help avoid vapor lock. Hot weather grades of gasoline are blended from lower volatility fuels to lessen the tendency toward vapor lock.

d. *Fuel Distribution.* When the fuel is not distributed evenly to all cylinders, the engine will run unevenly and power output will decrease. To ensure good distribution, the fuel must be vaporized completely and mixed with air in the manifold before entering the combustion chamber.

3. Gasoline Purity

Petroleum contains many impurities that must be removed during the refining process before gasoline suitable for automotive use is produced. At one time, considerable corrosion was caused by the sulfur inherent in petroleum products; however, modern refining processes have reduced it to almost negligible amounts. Another problem was the tendency for the hydrocarbons in the gasoline to oxidize into a sticky gum when exposed to air, resulting in clogged carburetor passages, stuck valves, and other operational difficulties. Chemicals that control gumming are now added to gasoline. Dirt, grease, water, and various chemicals also must be removed to make gasoline an acceptable fuel.

4. Deicing Agents

Moisture in gasoline tends to freeze in cold weather, causing clogged fuel lines and carburetor idle ports. Deicing agents are added to gasoline which mix with the moisture and act as an antifreeze to prevent freezing.

5. Antiknock Quality

a. *Combustion.* To understand what is meant by antiknock quality, let us first review the process of combustion. When any substance burns, it is actually uniting in rapid chemical reaction with oxygen (one of the constituents of air). During this process, the molecules of the substance and oxygen are set into very rapid motion and heat is produced. In the combustion chamber of an engine cylinder, the gasoline vapor and oxygen in the air are ignited and burn. They combine, and the molecules begin to move about very rapidly as the high temperatures of combustion are reached. The molecules, therefore, bombard the combustion chamber walls and the piston head with a shower of fast moving molecules. It is actually this bombardment that exerts the heavy push on the piston and forces it downward on the power stroke.

b. *Combustion Process.* The normal combustion process in the combustion chamber goes through three stages when producing power. They are as follows:

(1) *Formation of Nucleus of the Flame.* As soon as a spark jumps the gap of the spark plug electrode, a small ball of blue flame develops in the gap. This ball is the first stage, or nucleus, of the flame. It enlarges with relative slowness and, during its growth, there is no measurable pressure created by heat.

(2) *Hatching Out.* As the nucleus enlarges, it develops into the hatching out stage. The nucleus is torn apart so that it sends fingers of flame into the mixture in the combustion chamber. This causes only enough heat to give a slight rise in the temperature and pressure in the entire air-fuel mixture. Consequently, a lag still exists in the attempt to raise pressure in the entire cylinder.

(3) *Propagation.* It is during the third, or propagation stage that effective burning occurs. The flame now burns in a front that sweeps across the combustion chamber, burning rapidly and causing great heat with an accompanying rise in pressure. This pressure causes the piston to move downward. Burning during normal combustion is progressive. It increases gradually during the first two stages, but during the third stage, the flame is extremely strong as it sweeps through the combustion chamber.

c. *Detonation.* If detonation takes place, it will happen during the third stage of combustion. The first two stages are normal, but in the propagation stage, the flame sweeps from the area around the spark plug toward the walls of the combustion chamber. Parts of the chamber that the flame has passed contain inert gases, but the section not yet touched by the flame contains highly compressed, heated combustible gases. As the flame races through the combustion chamber, the unburned gases ahead of it are further compressed and are heated to higher temperatures. Under certain conditions, the extreme heating of the unburned part of the mixture may cause it to ignite spontaneously and explode.

This rapid, uncontrolled burning in the final stage of combustion is called detonation. It is caused by the rapidly burning flame front compressing the

unburned part of the mixture to the point of self-ignition. This secondary wavefront collides with the normal wavefront, making an audible knock or ping. It is an uncontrolled explosion, causing the unconfined gases in the combustion chamber to rap against the cylinder head walls. Detonation may harm an engine or hinder its performance in several ways. In extreme cases, pistons have been shattered, rings broken, or heads cracked. Detonation also may cause overheating, excessive bearing wear, loss of power, and high fuel consumption.

d. *Octane Rating.*

(1) The ability of a fuel to resist detonation is measured by its octane rating. The octane rating of a fuel is determined by matching it against mixtures of normal heptane and iso-octane in a test engine, under specified test conditions, until a pure mixture of hydrocarbons is found that gives the same degree of knocking in the engine as the gasoline being tested. The octane number of the gasoline then is specified as the percent of iso-octane in the matching iso-octane normal heptane mixture. For example, a gasoline rating of 75 percent octane is equivalent in its knocking characteristics to a mixture of 75 percent iso-octane and 25 percent normal heptane. Thus, by definition, normal heptane has an octane rating of 0 and iso-octane has an octane of 100 percent.

(2) The tendency of a fuel to detonate varies in different engines, and in the same engines under different operating conditions. The octane number has nothing to do with starting qualities, potential energy, volatility, or other major characteristics. Engines are designed to operate within a certain octane range. Performance is improved with the use of higher octane fuels within that operational range. Engine performance will not be improved if a gasoline with an octane rating higher than the operational range is provided.

(3) Tetraethyl lead is the most popular of the compounds added to gasoline to raise its octane rating. The introduction of catalytic converters, however, has created a need for a higher octane lead-free gasoline produced by more careful refining processes and numerous substitutes for lead. Lead-free gasolines to date, however, do not have the antiknock qualities of leaded ones.

Modern automotive engines made for use with lead-free gasoline must, therefore, be designed for lower octane ratings.

e. *Other Causes for Knocking.*

(1) Low-octane fuel is not the only reason for knocking. Anything that adds heat or pressure to the last part of the mixture to burn within a cylinder will aggravate detonation and also result in knocking. That is why the compression ratio of a gasoline engine has an upper limit. When the ratio is raised too high, the immediate result is detonation caused by excessive heat from the additional compression. Under certain conditions, excessive spark advance, lean fuel mixtures, and defective cooling systems are some of the many causes of detonation.

(2) Preignition is another cause for knocking. Though its symptoms are similar, it is not to be confused with detonation. Preignition is an igniting of the air-fuel mixture during compression before the spark occurs; it is caused by some form of hot spot in the cylinder, such as an overheated exhaust valve head or spark plug, or a glowing piece of carbon. Preignition can lead to detonation, but the two are separate and distinct events.

6. Conclusion

With a basic understanding of the characteristics of gasoline, it is a logical progression to learn about the function and construction of gasoline fuel systems which will be covered in the next task.

LESSON 1

FUNCTION AND CONSTRUCTION OF GASOLINE FUEL SYSTEMS

TASK 2. Describe the principles, construction, and function of gasoline fuel systems.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within two hours

REFERENCES

No supplementary references are needed for this task.

1. Introduction

This task illustrates the function of a gasoline fuel system. It will describe the principles and function for the following components of this system: fuel tank, fuel filter, fuel pump, fuel tank ventilation system, intake manifold, air filter, carburetor, carburetion choke system, and related carburetion components.

2. Fuel Tanks

a. *Purpose.* The fuel tank is for storage of gasoline in liquid form. The location of the fuel tank is dependent upon using an area that is protected from flying debris, shielded from collision damage, and not subject to bottoming of the vehicle. A fuel tank can be located just about anywhere in the vehicle that meets these requirements.

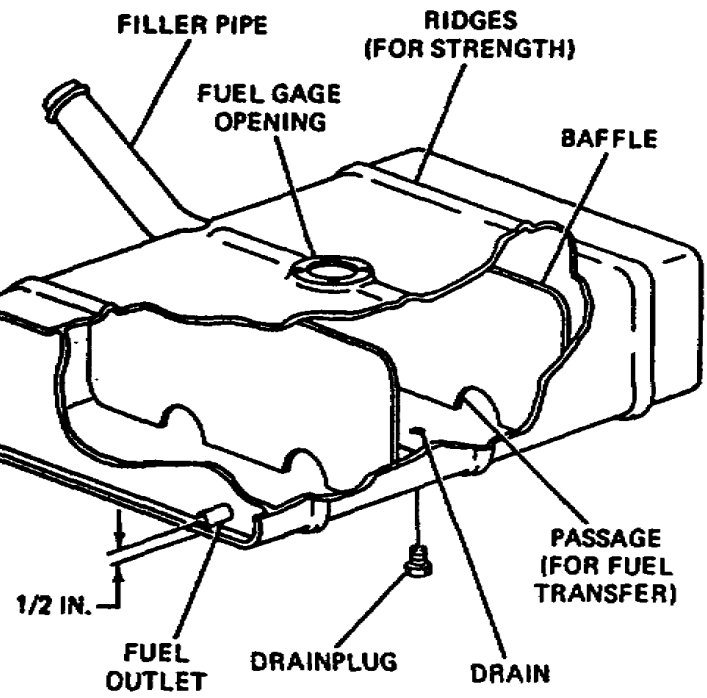
b. *Construction.* Fuel tanks take many forms in military vehicles such as those described below.

(1) The removable fuel tank (figure 1) is most commonly used in wheeled vehicles. The most common material for fuel tanks is thin sheet metal coated with lead-tin alloy to prevent corrosion. Because corrosion is a major concern, fiberglass and a variety of molded plastics are also widely used in the manufacture of fuel tanks.

The walls of the tank are manufactured with ridges to give strength. Internal baffles are installed in the tank to prevent the fuel from sloshing and to increase its overall strength. Some tanks are made with a double wall with a layer of latex rubber in between. The purpose of the wall is to make the tank self-sealing.

(2) The fuel cell is a compartment that is integral with the body or the hull of the vehicle. Fuel cells can be located anywhere there is an empty space. They are used in vehicles that require a large fuel storage capacity. A fuel cell can take advantage of hollow areas of the vehicle where use of a removable fuel tank would be impractical. Fuel cells are particularly suited for combat situations because they may be located in areas that provide a maximum of shielding.

FIGURE 1. TYPICAL REMOVABLE FUEL TANK CONSTRUCTION.



(3) The bladder-type fuel cell is much the same as the fuel cell described above, except for the addition of a flexible liner. The liner serves to seal the cell much as an inner tube seals a tire.

c. *Filler Pipe.* A pipe is provided for filling the tank or cell, designed to prevent fuel from being spilled into the passenger, engine, or cargo compartments. The filler pipes used on military vehicles are designed to allow their tanks or cells to be filled at a rate of at least 50 gallons per minute.

d. *Fuel Outlet.* The outlet pipe (figure 1 on the previous page) is located approximately 1/2 inch above the bottom of the fuel tank or cell. This location allows sediment to fall to the bottom of the tank or cell without it being drawn into the fuel system.

e. *Fuel Gage Provision.* A provision usually is made to install a fuel gage. This provision is usually in the form of a flanged hole.

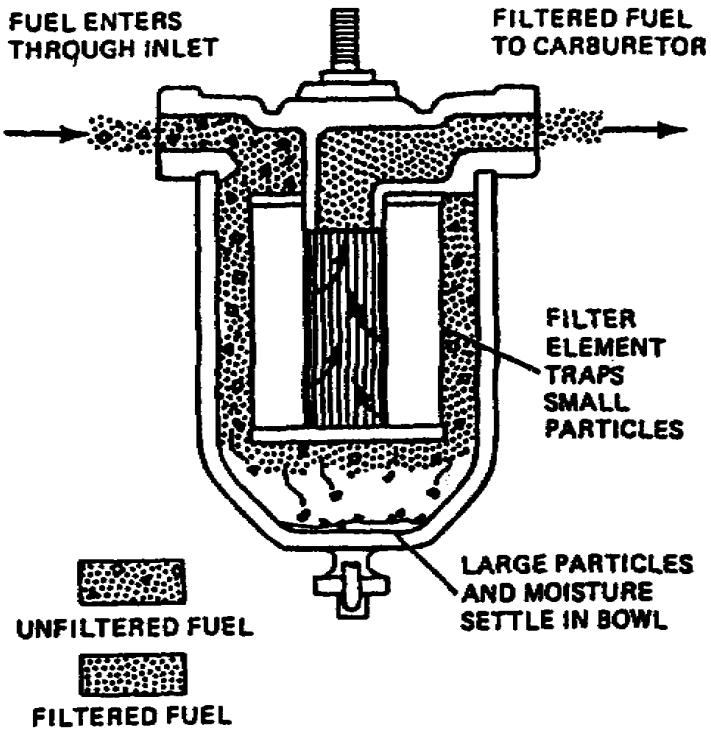
f. *Drainplug.* The threaded drainplug shown in figure 1, is provided at the bottom of the tank for draining and cleaning the tank.

3. Fuel Filters

a. *Purpose.* The fuel filter traps foreign material that may be present in the fuel, preventing it from entering the carburetor or sensitive fuel injection components. At least one fuel filter is used in any fuel system. A fuel filter can be located in any accessible place along the fuel delivery line. Filters also can be located inside fuel tanks, carburetors, and fuel pumps.

b. *Operation.* Fuel filters (figure 2 on the following page) operate by passing the fuel through a porous filtering medium. The openings in the porous material are very small and, as a result, any particles in the fuel that are large enough to cause problems are blocked. In addition to the filtering medium, the filter in most cases also serves as a sediment bowl. The gasoline, as it passes through the filter, remains in the sediment bowl for sufficient time to allow large particles and water to settle out of it.

FIGURE 2. FUEL FILTER OPERATION.


FUEL ENTERS THROUGH INLET
FILTERED FUEL TO CARBURETOR
FILTER ELEMENT TRAPS SMALL PARTICLES
LARGE PARTICLES AND MOISTURE SETTLE IN BOWL
UNFILTERED FUEL
FILTERED FUEL

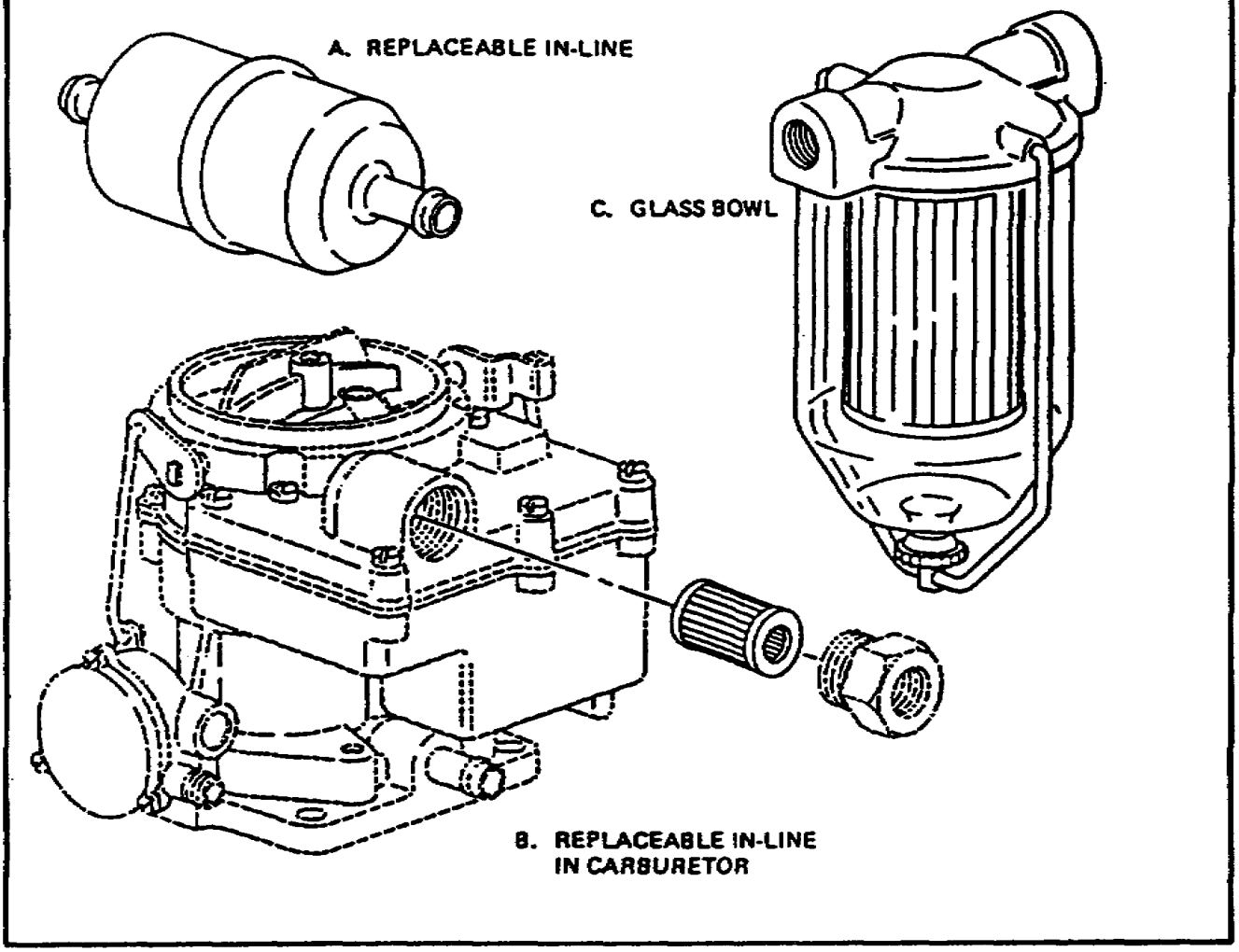
c. *Fuel Filter Configurations.* The various types of fuel filters are:

(1) *Replaceable In-Line Filter* (figure 3, view A, on the following page). This type of filter is periodically replaced. The body of the filter acts as a sediment bowl.

(2) *In-Line Filter Elements.* (Elements that fit in the carburetor inlet or inside the fuel tank on the outlet) (figure 3, view B, on the following page). These filters are replaceable at intervals and contain no sediment bowls.

(3) *Glass Bowl Filter with Replaceable Element* (figure 3, view C, on the following page). The sediment bowl must be washed out whenever the element is replaced. Some fuel pumps have a glass bowl-type gas filter built in.

FIGURE 3. REPLACEABLE IN-LINE FILTER.



d. *Element Configurations.* Filter elements are made from ceramic, treated paper, sintered bronze, or metal screen. There is one filter element that differs from all others. It consists of a pile of laminated disks spaced 0.0003 inches apart. As the gasoline passes between the disks, foreign matter is blocked out.

4. Fuel Pumps

a. *Purpose.* The fuel pump delivers gasoline from the fuel tank to the engine. Early automotive equipment used gravity to feed gasoline to the engine. This is no longer practical because it limits the location of the fuel tank to positions that are above the engine.

b. *Mechanical-Type.* The mechanical-type of fuel pump is generally the more popular pump used for gasoline engine applications. It is usually more than adequate and is much cheaper than an electric pump. The electric pump is more desirable, however, for the following reasons:

(1) The electric pump will supply fuel to the engine immediately after the ignition key is turned on. The engine must be tuned by the starter for a mechanical pump to operate.

(2) The pump, by design, will operate more efficiently if it pushes the fuel rather than pulling it. An electric pump can be mounted close to the tank, or in the tank, to take advantage of this characteristic.

(3) The electric pump can be mounted away from heat to reduce the possibility of vapor lock.

c. *Mechanical, Nonpositive-Type* (figure 4 on the following page). This is currently the most popular configuration of an automotive fuel pump. Operation is as follows:

(1) The rocker arm is moved up and down by the engine camshaft. The rocker arm spring causes the rocker arm to follow the cam lobe.

(2) The rocker arm hooks into an elongated slot in the pull rod. The other end of the pull rod is attached to the diaphragm.

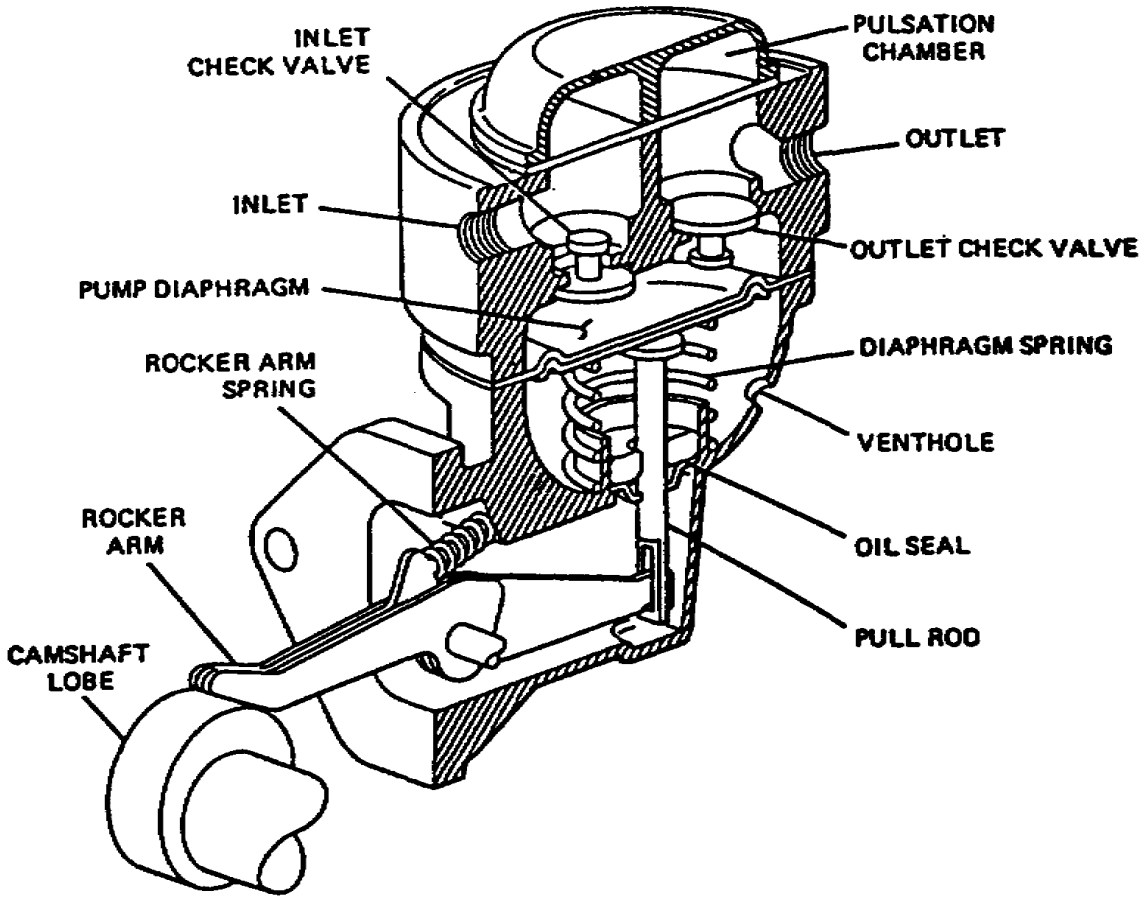
(3) As the camshaft operates the rocker arm, it will operate the diaphragm against the force of the diaphragm spring.

(4) As the rocker arm pulls the diaphragm down, the inlet check valve is unseated and fuel is drawn into the pump chamber. The outlet check valve seals the outlet passage.

(5) As the diaphragm spring pushes the diaphragm back up, the inlet check valve seals the inlet and the fuel in the pump chamber is pushed through the outlet check valve and through the pump outlet.

(6) The action is repeated each time the rocker arm operates the diaphragm.

FIGURE 4. MECHANICAL NONPOSITIVE TYPE FUEL PUMP.



(7) Pressure will build in the fuel line and the pump chamber as the fuel pump fills the carburetor bowl. As the pressure rises to the desired level in the pump chamber, it will hold the diaphragm down against the pressure of the diaphragm spring. The rocker arm will move up and down in the slotted pull rod. There will be no pumping action until the fuel line pressure again drops below the desired level. In this way, the nonpositive-type fuel pump regulates fuel line pressure. Normal pressure range is from 1.5 to 6 pounds per square inch (psi). The operating range of the pump depends on the tension exerted by the diaphragm spring.

(8) A venthole is provided under the diaphragm to allow the pressure to change in the lower chamber as the diaphragm flexes.

(9) The pulsation chamber, located above the pump chamber, uses a soft diaphragm and a sealed

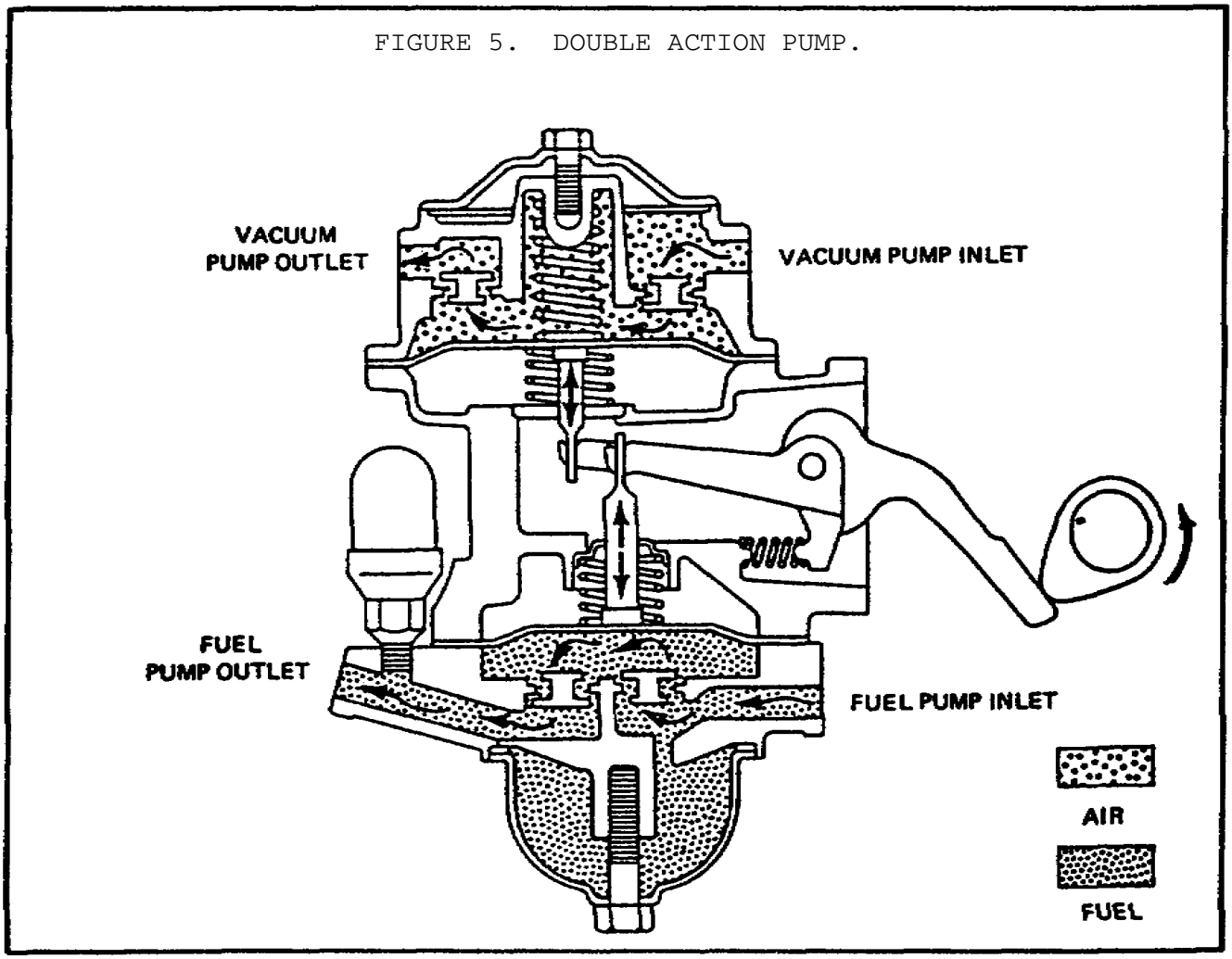
chamber to cushion the pulsating action inherent to the diaphragm-type pump.

(10) An oil seal is provided to keep crankcase oil from entering the lower chamber and leaking from the venthole.

d. *Mechanical, Positive Type.* The positive-type mechanical pump operates in the same manner as the nonpositive-type. The difference is that the diaphragm pull rod is solidly linked to the rocker arm. The pump, therefore, will not regulate fuel line pressure. When this type of pump is used, a separate fuel pressure regulation device must be employed which will bypass excess fuel back to the fuel tank.

e. *Double Action Fuel Pump* (figure 5). Vehicles that use vacuum-operated windshield wipers will often use a supply pump that is built into the fuel pump. The pump serves to operate the windshield wipers during periods of high engine load when the

FIGURE 5. DOUBLE ACTION PUMP.



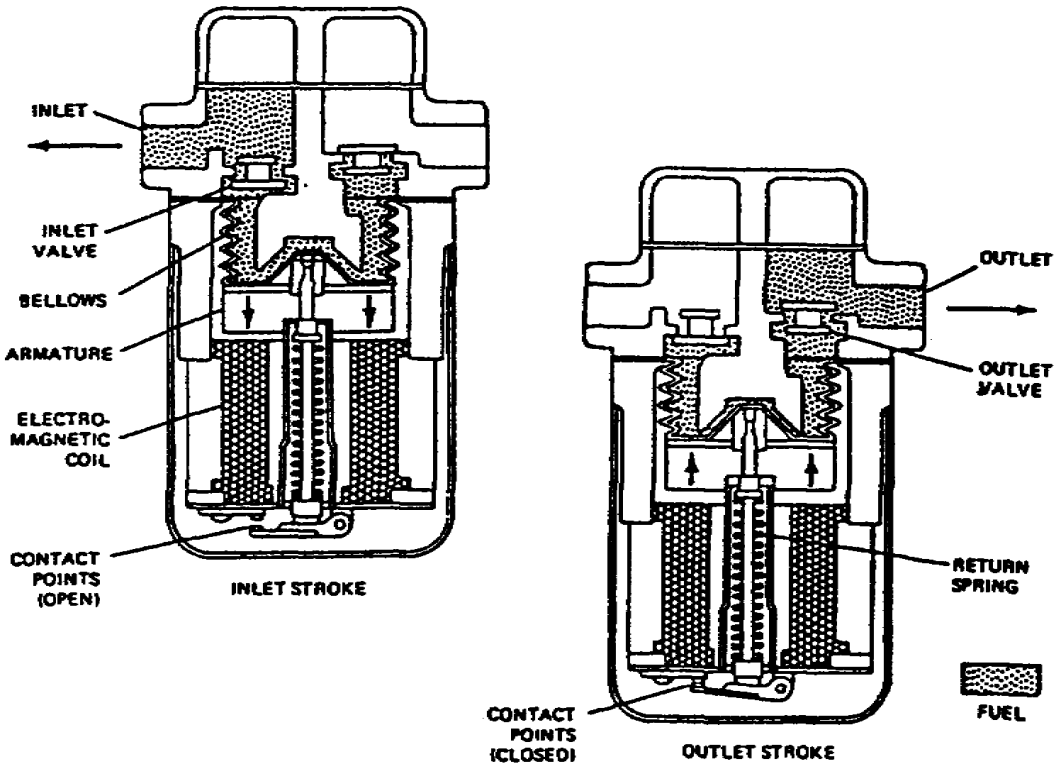
manifold vacuum is low. The pump operates from a rocker arm and is a nonpositive-type diaphragm pump. At times when the manifold vacuum alone is sufficient to operate the windshield wipers, the diaphragm will be held up against the diaphragm spring by atmospheric pressure, rendering the pump inoperative.

f. *Electric, Bellows-Type* (figure 6). The bellows-type electric fuel pump works in the same manner as the nonpositive-type mechanical pump. The difference is that it is driven by an electric solenoid rather than a mechanical camshaft. Operation is as follows:

(1) As electric current is fed to the pump, the electromagnetic coil pulls the armature down, expanding the bellows.

(2) The expansion of the bellows causes fuel to be drawn in through the inlet valve.

FIGURE 6. BELLOWS-TYPE ELECTRIC FUEL PUMP.



(3) As the bellows are fully expanded, a pair of contact points are open, switching off the electromagnet.

(4) The return spring pushes the armature back up contracting the bellows. This action pushes the fuel out of the pump through the outlet valve.

(5) The contact points are closed as the bellows are fully contracted. This causes the electromagnet to pull the armature down and repeat the pumping process.

(6) The pump will stop when the fuel pressure is high enough to hold the bellows expanded against the return spring. The operating pressure of the pump is determined by the return spring pressure.

5. Fuel Tank Ventilation Systems

a. *Purpose.* The fuel tank needs a ventilation system to keep the pressure within it equal to atmospheric pressure. This is important for the following reasons:

(1) Air must be allowed to enter the tank as the fuel is pumped out. Without ventilation of the tank, the pressure in the tank would drop to the point where the fuel pump would not be able to draw fuel from it. In some cases, the higher pressure around the outside of the tank could cause it to collapse.

(2) Temperature changes cause the fuel in the tank to expand and contract. Absence of a ventilation system could cause excessive or insufficient fuel line pressure.

b. *Configurations.* The most common methods of venting a fuel tank are:

(1) By venting the fuel tank cap to the atmosphere. This method was the most common on earlier passenger cars and trucks. It still is used on vehicles not subject to emission control regulations or that are not used for fording.

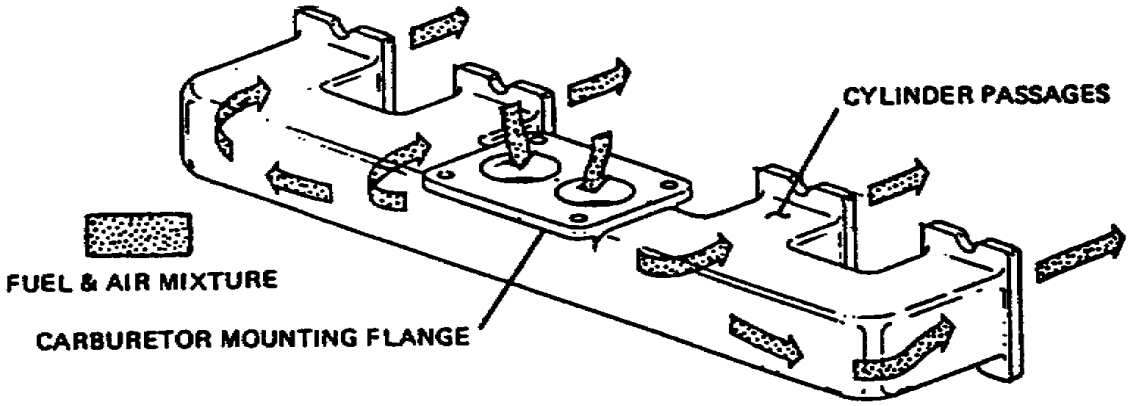
(2) By providing a line to the fuel tank that vents the fuel tank at a point high enough to prevent water from entering when fording water.

(3) Vehicles that are subject to emission control regulations have fuel tank ventilation systems that work in conjunction with the evaporation control system.

6. Intake Manifold

a. *Description* (figure 7). A properly designed intake manifold should perform the following functions:

FIGURE 7. TYPICAL INTAKE MANIFOLD.



(1) Deliver the mixture to the cylinders in equal quantities and proportions. This is important for smooth engine performance. The length of the passages should be as near equal as possible to distribute the mixture equally.

(2) Help to keep the vaporized mixture from condensing before it reaches the combustion chamber. Because the ideal mixture should be vaporized completely as it enters the combustion chamber, this is very important. To reduce condensation of the mixture, the manifold passages should be designed with smooth walls and a minimum of bends, which collect fuel. Smooth flowing intake manifold passages also increase volumetric efficiency.

(3) Aid in the vaporization of the mixture. To do this, the intake manifold should provide a controlled system of heating. This system of heating must heat the mixture enough to aid in

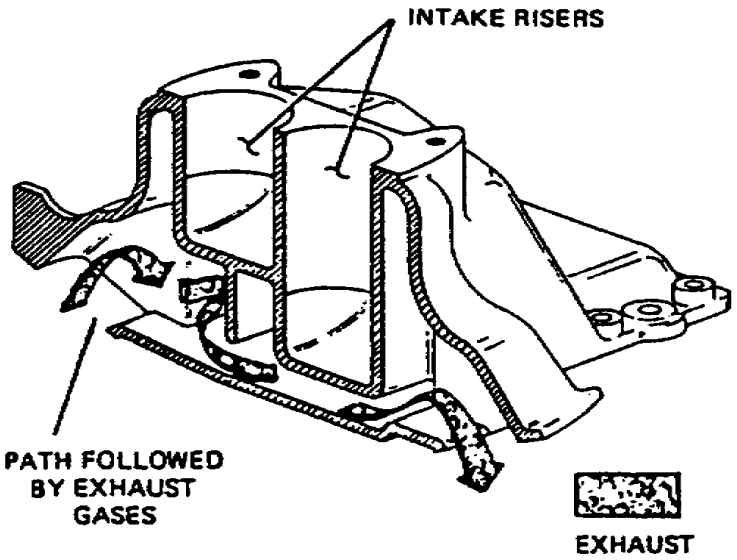
vaporization without heating to the point of significantly reducing volumetric efficiency.

b. *Ram Induction.* Intake manifolds can be designed to provide optimum performance for a given engine speed range by varying the length of the passages. The inertia of the moving intake mixture will cause it to bounce back and forth in the manifold passage from the end of one intake stroke to the beginning of the next intake stroke. If the passage is then the proper length, so that the next intake stroke is just beginning as the mixture is rebounding, the inertia of the mixture will cause it to ram itself into the cylinder. This will increase the volumetric efficiency of the engine in the designated speed range. It should be noted that the ram manifold will serve no useful purpose outside of its designated speed range.

c. *Heating the Mixture.* Providing controlled heat for the incoming mixture is very important for good performance. The heating of the mixture may be accomplished by one or both of the following:

(1) Directing a portion of the exhaust through a passage in the intake manifold (figure 8). The heat from the exhaust that is diverted into the intake manifold heat passage is controlled by a manifold heat control valve.

FIGURE 8. EXHAUST-HEATED INTAKE MANIFOLD.



(2) Directing the engine coolant, which is laden with engine heat, through the intake manifold on its way to the radiator.

7. Air Filters

a. *Purpose.* The air filter fits over the engine air intake to filter out particles of foreign matter. Any foreign matter that enters the intake will act as an abrasive between the cylinder walls and the pistons, greatly shortening engine life. Two types of filters in use are the wet the and dry types.

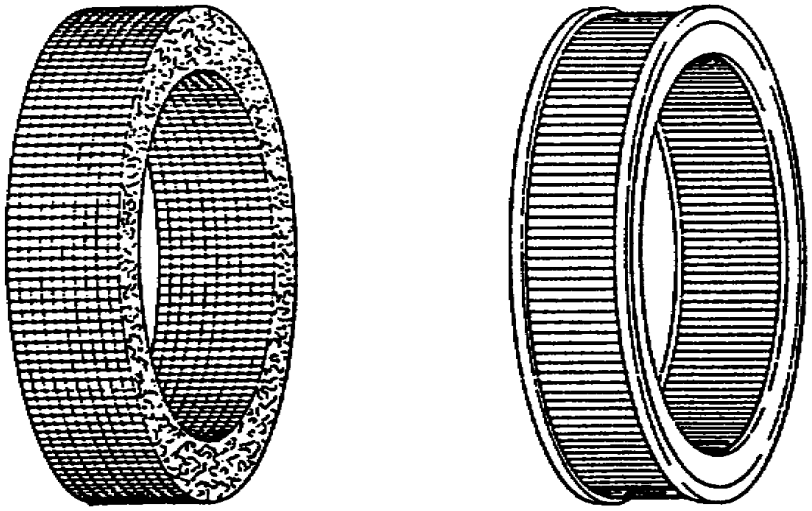
b. *Wet-Type.* The wet-type, or oil bath air filter, consists of the main body, the filter element that is made of woven copper gauze, and the cover. Operation is as follows: The incoming air enters between the cover and the main body. It is pulled down to the bottom of the main body, where it must make a 180° turn as it passes over the oil reservoir. As the air passes over the oil reservoir, most of the particles will not make the turn; they will hit the oil and be trapped. As the air continues upward and passes through the filter element, smaller particles that bypassed the oil will be trapped. The air keeps the filter element soaked with oil by creating a fine spray as it passes the reservoir. The air finally makes another 180° turn and enters the carburetor.

c. *Dry-Type* (figure 9 on the following page). The dry-type air filter passes the incoming air through a filtering medium before it enters the engine. The filtering medium consists of oil-soaked copper mesh or replaceable pleated paper, the latter being the most common.

8. Principles of Carburetion

a. *Composition of Air.* Air is composed of various gases, mostly nitrogen and oxygen (78 percent nitrogen and 21 percent oxygen by volume). These gases are composed of tiny particles called molecules as are all substances. In the air surrounding the earth, the molecules are able to move quite freely in relation to each other as in all gases. The molecules of air are attracted to the earth by gravity, creating the atmosphere. The weight of the air molecules creates atmospheric pressure.

FIGURE 9. DRY-TYPE AIR FILTERS.



b. *Evaporation.* Evaporation is the changing of a liquid to a vapor. The molecules of the liquid, not being closely tied together, are constantly moving about among themselves. Any molecule that moves upward with sufficient speed will jump out of the liquid and into the air. This process will cause the liquid to evaporate over a period of time. The rate of evaporation is dependent on the following:

(1) *Temperature.* The rate of movement of the molecules increases with temperature. Because of this, the amount of molecules leaving the liquid in a given time will increase as the temperature increases.

(2) *Atmospheric Pressure.* As atmospheric pressure increases, the amount of air molecules present over the liquid also increases. The increased presence of air molecules will slow the rate of evaporation. This is because the molecules of liquid will have more air molecules to collide with. In many cases, they will fall back into the liquid after collision.

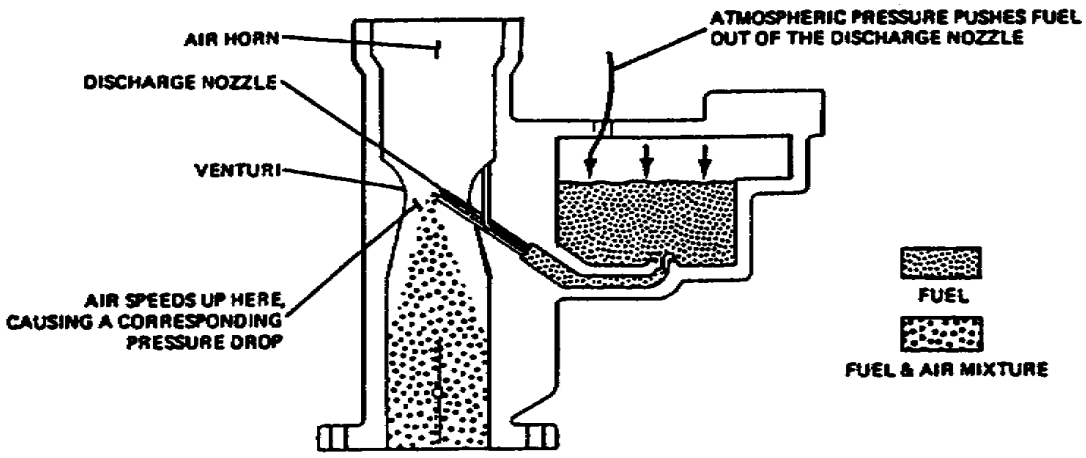
(3) *Closed Chamber.* As evaporation takes place in a closed container, the space above the liquid will reach a point of saturation. When this happens, every molecule of liquid that enters the air will cause another airborne molecule of liquid to fall back.

(4) *Volatility.* The term volatility refers to how fast a liquid vaporizes. Alcohol, for instance, vaporizes more easily than water. Some liquids vaporize easily at room temperature. A highly volatile liquid is one that is considered to evaporate easily.

c. *Venturi Effect* (figure 10). A venturi effect is used by the carburetor to mix gasoline with air. The basic carburetor has an hourglass shaped tube called a throat. The most constricted part of the throat is called the venturi. A tube called a discharge nozzle is positioned in the venturi. The discharge nozzle is connected to a reservoir of gasoline, called the float bowl. The negative pressure that exists in the combustion chamber, because of the downward intake stroke of the piston, causes atmospheric pressure to create an airflow through the carburetor throat. This airflow must increase temporarily in speed as it passes through the venturi, due to its decreased size.

The increased speed of the airflow will also result in a corresponding decrease in pressure within the venturi and at the end of the discharge nozzle. When this occurs, atmospheric pressure will push gasoline through the discharge nozzle and into the carburetor throat, where it will mix with the intake airflow.

FIGURE 10. VENTURI EFFECT.


AIR HORN
DISCHARGE NOZZLE
VENTURI
AIR SPEEDS UP HERE, CAUSING A CORRESPONDING PRESSURE DROP
ATMOSPHERIC PRESSURE PUSHES FUEL OUT OF THE DISCHARGE NOZZLE
FUEL
FUEL & AIR MIXTURE

d. *A Basic Carburetor.* The ideal state for the fuel to be in when it reaches the cylinder is to be vaporized completely. Good intake manifold design will help to vaporize the fuel, but the carburetor must properly atomize the fuel beforehand. Atomization of the fuel occurs as it is drawn into the venturi. As the fuel comes out of the discharge nozzle, it is broken into tiny droplets which enter the airflow. To ensure that there is a high degree of atomization, a tiny hole called an air bleed is used to allow air to mix with the fuel in the discharge tube. The fuel is then further atomized as it enters the venturi. To ensure proper fuel flow, a secondary venturi or a venturi booster may be used. It will further decrease the pressure at the discharge nozzle.

e. *Air-Fuel Ratio.* The proportions of an air-fuel mixture are expressed in terms of the air-fuel ratio. It is the relationship by weight of the mixture. An example of how this is expressed would be:

Air-Fuel Ratio = 12:1.

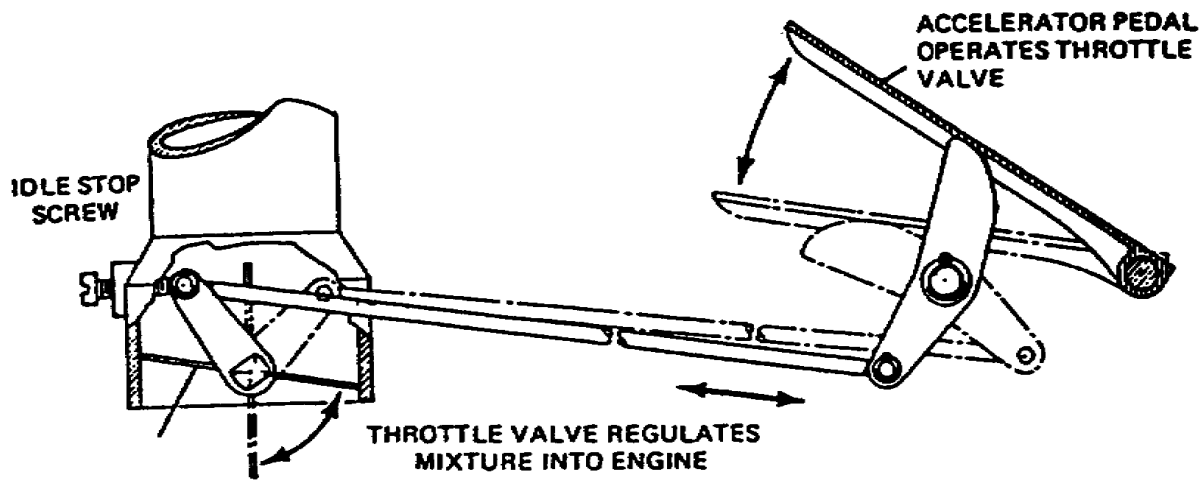
In this air-fuel mixture, the air would be 12 times as heavy as the fuel. The operational range of air-fuel ratios in the average gasoline engine are from approximately 9:1 to approximately 17:1. Air-fuel ratios on the lower end (less air) are considered to be rich mixtures; the air-fuel ratios at the higher end (more air) are considered to be lean mixtures. A gasoline engine, propelling a vehicle at a steady speed, operates on an air-fuel ratio of approximately 15:1. Considering that gasoline weighs approximately 640 times as much as air, it can be seen that a gasoline engine consumes a tremendous amount of air. If, in fact, the air-fuel ratio was considered by volume rather than weight, it would be seen that a gasoline engine operating on an air-fuel ratio of 15:1 consumes approximately 9600 gallons of air for every gallon of gasoline.

9. Construction of the Basic Carburetor

a. *Throttle Valve* (figure 11 on the following page). The throttle valve is used to regulate the speed and power output of the engine. It is controlled by the accelerator pedal, and usually consists of a flat, round plate that tilts with the throttle shaft. As the accelerator pedal is fully

depressed, the throttle valve is moved from a position of completely restricting the throat to being completely open. An idle stop screw is used to keep the throttle valve open slightly so that the engine may run at a regulated idle speed with no foot pressure on the accelerator. This screw may be turned in or out to regulate engine idle speed.

FIGURE 11. THROTTLE VALVE.



b. *Float Circuit.*

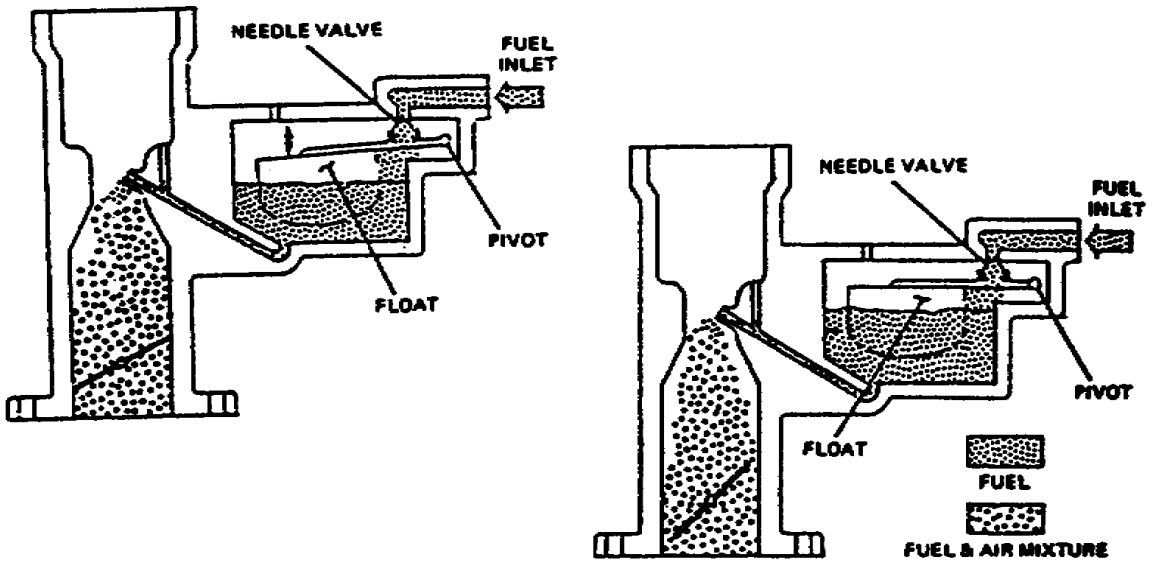
(1) *Purpose.* The float circuit maintains a steady working supply of gasoline at a constant level in the carburetor. This is very critical to proper engine performance. An excessively high float level will cause fuel to flow too freely from the discharge tube, causing an overly rich mixture; whereas an excessively low float level will cause an overly lean mixture.

(2) *Operation* (figure 12 on the following page). The fuel pump delivers gasoline under pressure to the carburetor. The following events occur as the gasoline enters the carburetor through the fuel inlet:

(a) The gasoline begins to fill the float bowl.

(b) The float rises with the level of the gasoline.

FIGURE 12. FLOAT CIRCUIT.



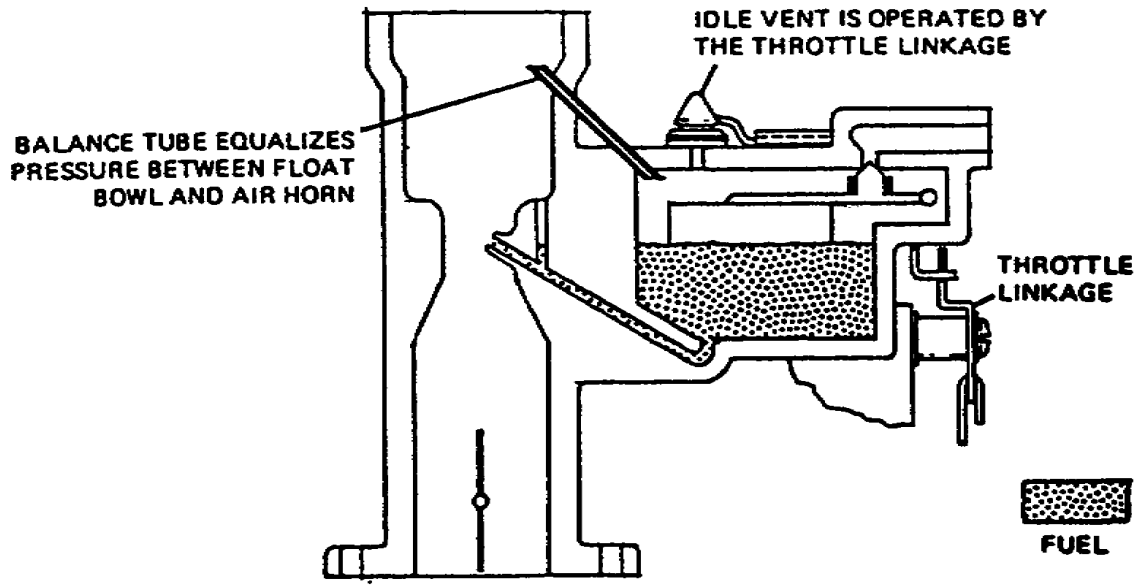
(c) The needle valve is closed by the rising float as the fuel reaches the desired level in the float bowl.

(3) As the engine uses the gasoline from the float bowl, the level will drop. This will cause the float to drop, which will open the needle valve to let in more fuel.

(4) *Venting* (figure 13 on the following page). The pressure in the float bowl must be regulated to assure the proper delivery of fuel and purging of vapors. The following systems and devices are added to the float circuit system to provide for these needs.

(a) *Balance Tube.* Due to the restrictions imposed by the air filter and changing air velocities because of varying engine speeds, the air pressure in the air horn is usually lower than atmospheric pressure. The pressure in the float bowl must equal that of the air horn in order for the carburetor to provide fuel delivery. A tube called a balance tube is run between the air horn and the float bowl to accomplish this task.

FIGURE 13. CONTROLLING FUEL BOWL PRESSURE.

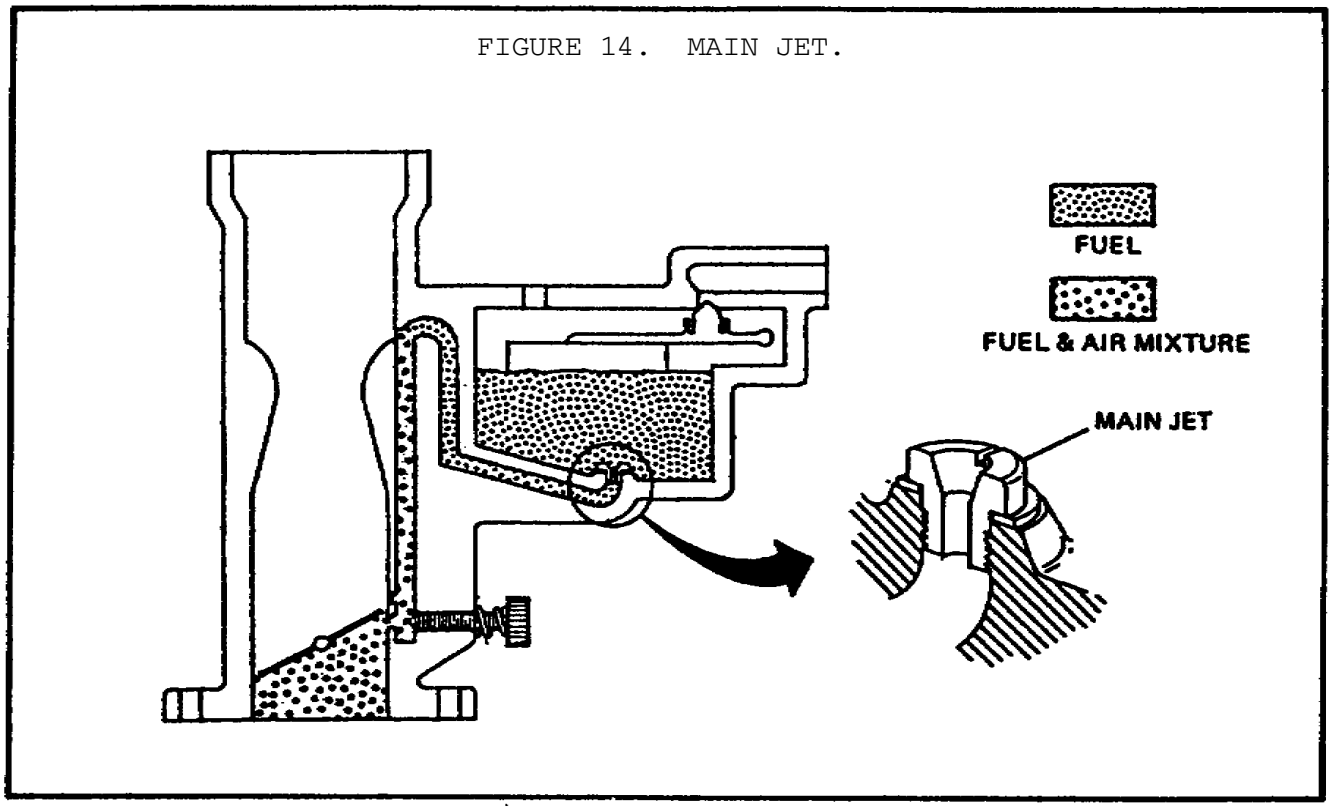

IDLE VENT IS OPERATED BY THE THROTTLE LINKAGE
BALANCE TUBE EQUALIZES PRESSURE BETWEEN FLOAT BOWL AND AIR HORN
THROTTLE LINKAGE
FUEL

(b) *Idle Vent.* Because gasoline is highly volatile, it can create overly rich mixtures during long periods of engine idle. This is because the fuel begins to evaporate in the float bowl and the vapors get into the air horn through the balance tube. The solution to this problem is to have an outside vent for the float bowl which is opened whenever the engine is idling. The idle vent is activated by linkage from the throttle valve. The idle vent system on later vehicles may be part of the emission control system.

10. Systems of the Carburetor

a. *General.* The two operating systems of the carburetor each contain two circuits providing the flexibility to operate throughout the entire engine speed range. Both of these systems obtain gasoline from the float bowl through the main jet (figure 14 on the following page). The main jet is a precisely sized opening that helps govern the amount of fuel used. The main jet is usually replaceable and is available in a variety of sizes. Carburetors can be tailored to meet various needs by varying jet sizes. In addition to the above, the carburetor must provide other systems to compensate for temperature change and for quick changes in throttle position.

FIGURE 14. MAIN JET.



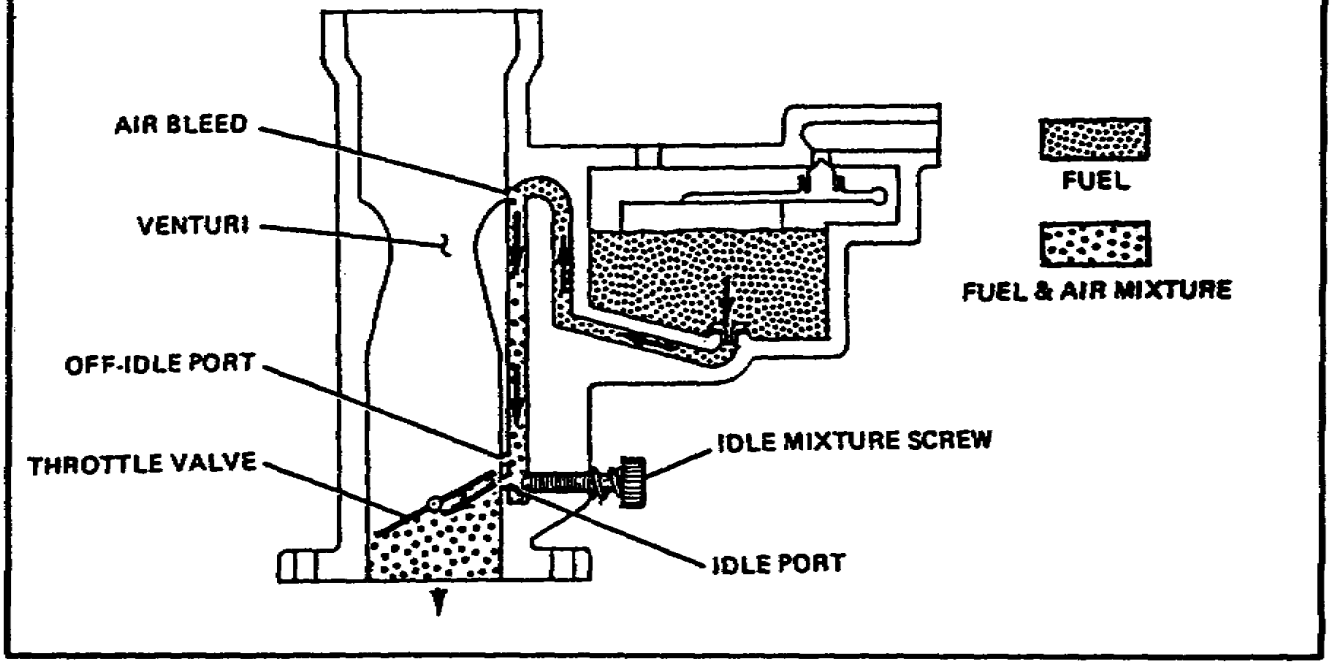
b. *Idle and Low-Speed System.*

(1) *Purpose.* The idle and low-speed system provides the proper air-fuel mixture when the engine is at idle and during other periods of small throttle opening. During these periods, there is not enough air flowing through the throat to make the discharge nozzle work.

(2) *Operation* (figure 15 on the following page). The idle and the low-speed portions of the system are really separate circuits in operation. The idle circuit sustains the engine at idle. As the throttle begins to open, the effectiveness of the idle circuit falls off gradually as the low-speed circuit takes over. The transition between the two circuits is a smooth one. Operation from engine idle through low-speed range is as follows:

(a) The throttle valve is almost closed at engine idle. This creates a high vacuum in the area of the carburetor under the throttle valve. This high vacuum causes atmospheric pressure to push gasoline through the idle port from the float bowl. The gasoline mixes with the air that is drawn in around the throttle valve. The mixture then is drawn into the engine.

FIGURE 15. IDLE AND LOW-SPEED SYSTEMS.



(b) As the throttle valve is opened, the vacuum under it begins to fall off, causing less gasoline to be drawn from the idle port. As more air flows through the throat, the gasoline will begin flowing through the low speed or off-idle discharge port, which is usually in the shape of a rectangular slot or a series of two or three holes. During the low-speed system operation, there is still not enough airflow through the throat for the discharge nozzle to work.

(3) *Idle Mixture Screw.* A needle shaped screw is used in the carburetor to regulate the idle port opening. The air-fuel ratio of the idle system can be adjusted by turning the screw in or out.

(4) *Air Bleeds.* Air bleeds also are used in the idle and low-speed circuits to help atomize the fuel.

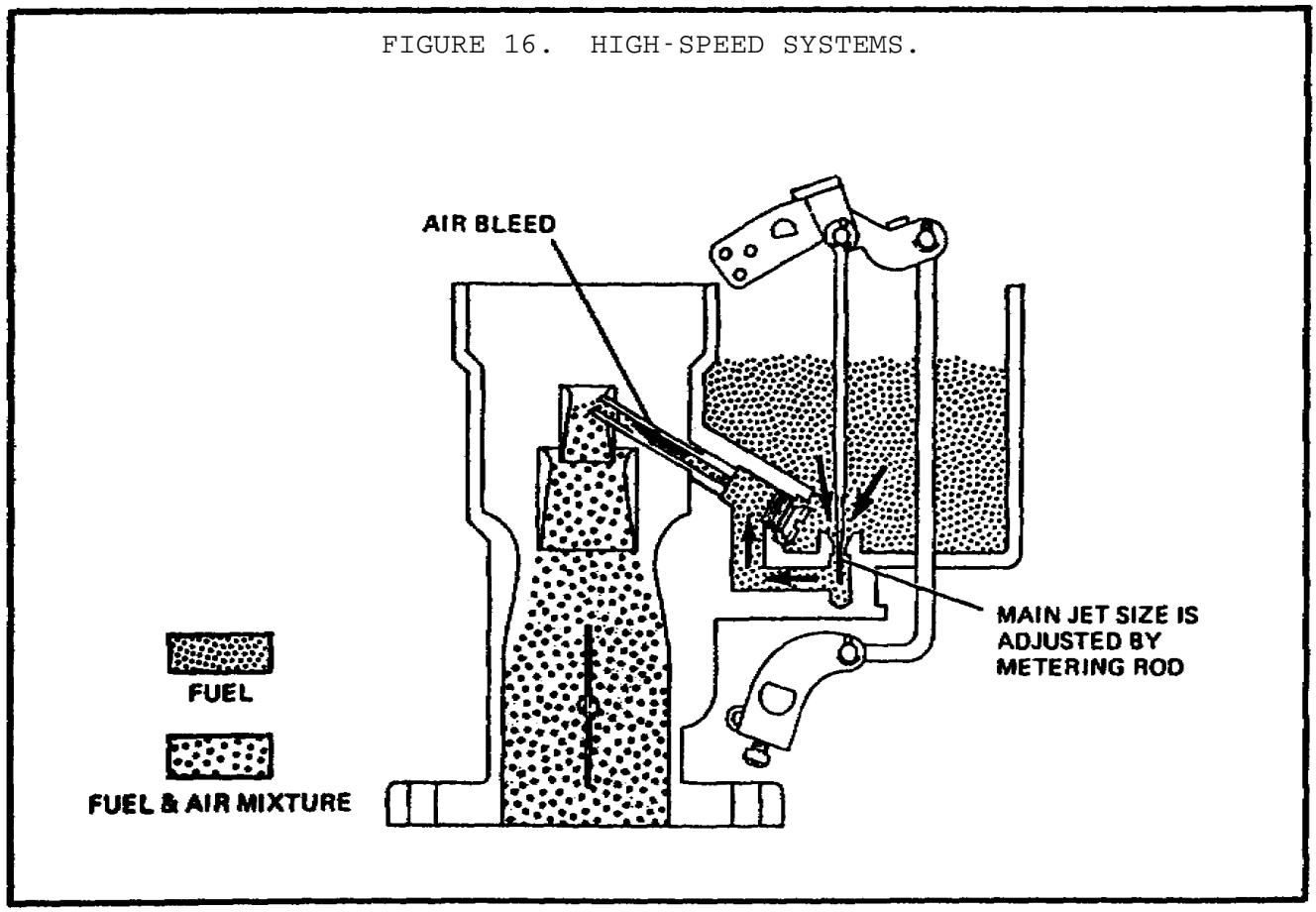
(5) *Passage to Float Bowl.* The passage that supplies the idle and low-speed circuits must (at some point) be higher than the level of the gasoline in the float bowl. If this passage went straight to the idle and low-speed ports, the float bowl would be able to drain through them.

c. *High-Speed and High-Speed Enrichment Circuits.*

(1) *Purpose.* The high-speed circuit supplies the fuel-air mixture to the engine during medium to full throttle valve opening. The high-speed circuit gradually will take over from the low-speed circuit as the throttle is depressed. The carburetor is designed to provide approximately a 16:1 to 17:1 air-fuel ratio under normal, steady speed conditions. The high-speed enrichment circuit will enrich the mixture to approximately 11:1 to 12:1 if a heavy demand is placed on the engine.

(2) *Operation* (figure 16). The high-speed circuit takes its gasoline from the float bowl through the main jet. The gasoline is fed through a passageway to the discharge nozzle, where it sixes with the air in the venturi. Opening the throttle valve and accelerating the engine speed increases the airflow in the venturi, which causes a proportional increase in the amount of gasoline from the discharge nozzle. The high-speed enrichment system increases the fuel flow to the discharge nozzle by either increasing the main jet

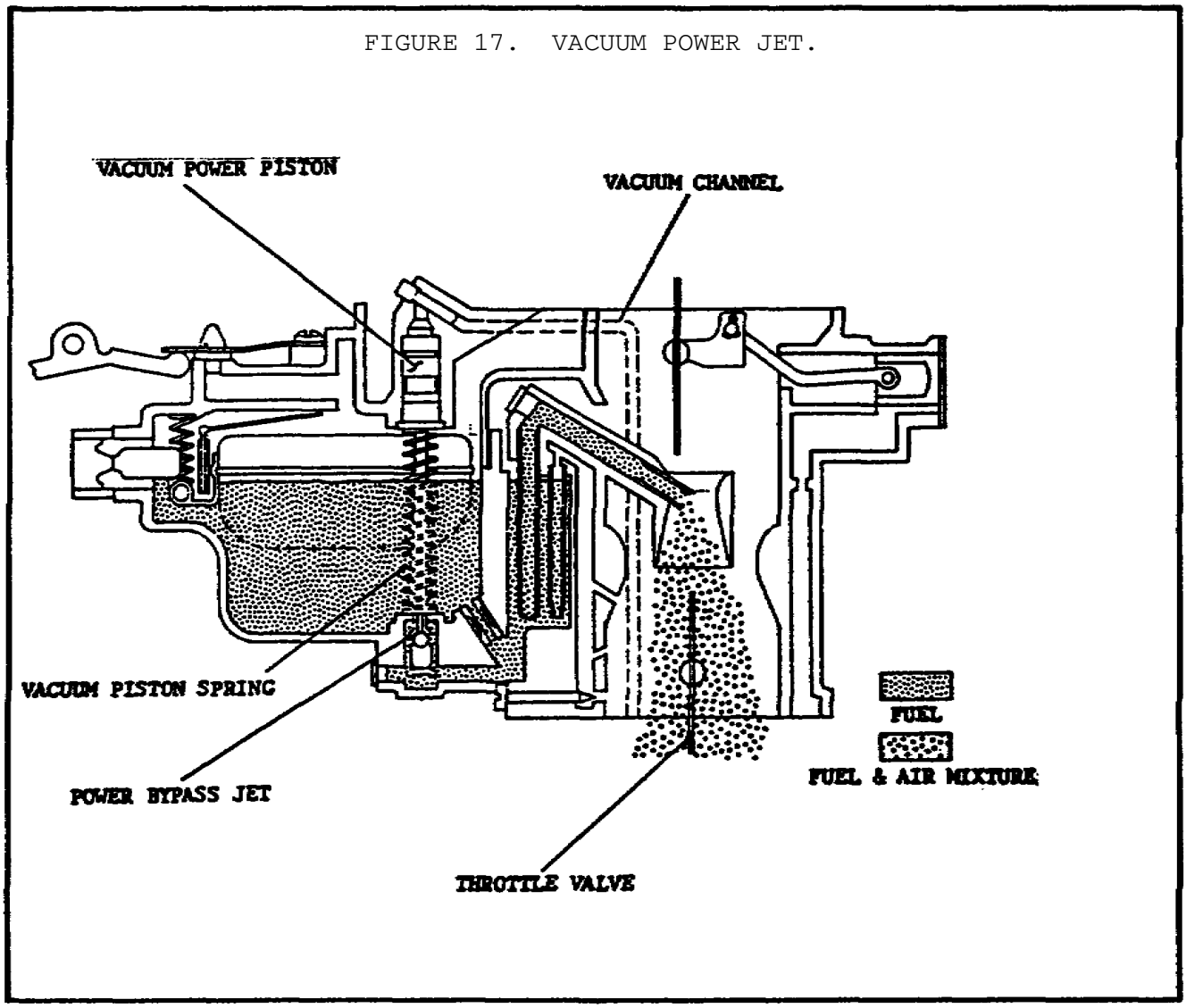
FIGURE 16. HIGH-SPEED SYSTEMS.



opening, or by providing a second supply of fuel from the float bowl. Three basic high-speed enrichment systems are power jet, vacuum-operated metering rod, and mechanically operated metering rod.

(a) *Power Jet* (figure 17). The power jet system includes a jet that is opened by a vacuum operated piston. The jet provides an extra supply of fuel to the discharge nozzle from the float bowl. When the throttle valve is not opened wide, there will be high manifold vacuum because the carburetor throat is restricted. This high manifold vacuum is used to hold the vacuum piston against its spring. When the piston is up, the spring in the power jet will hold it closed. The throttle valve is opened when extra power is demanded, causing a drop in manifold vacuum. As manifold vacuum drops, the spring on the vacuum

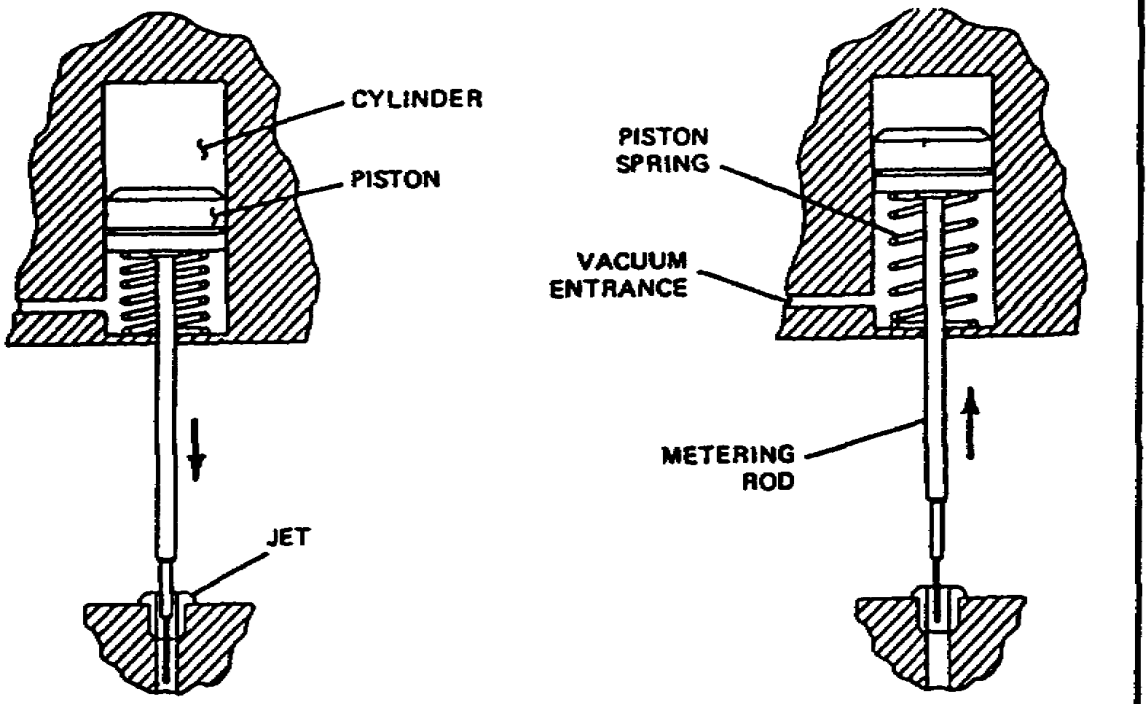
FIGURE 17. VACUUM POWER JET.



piston pushes the piston down, which in turn pushes the power valve open. The power jet is sometimes referred to as the economizer and the vacuum piston as the step-up or power piston.

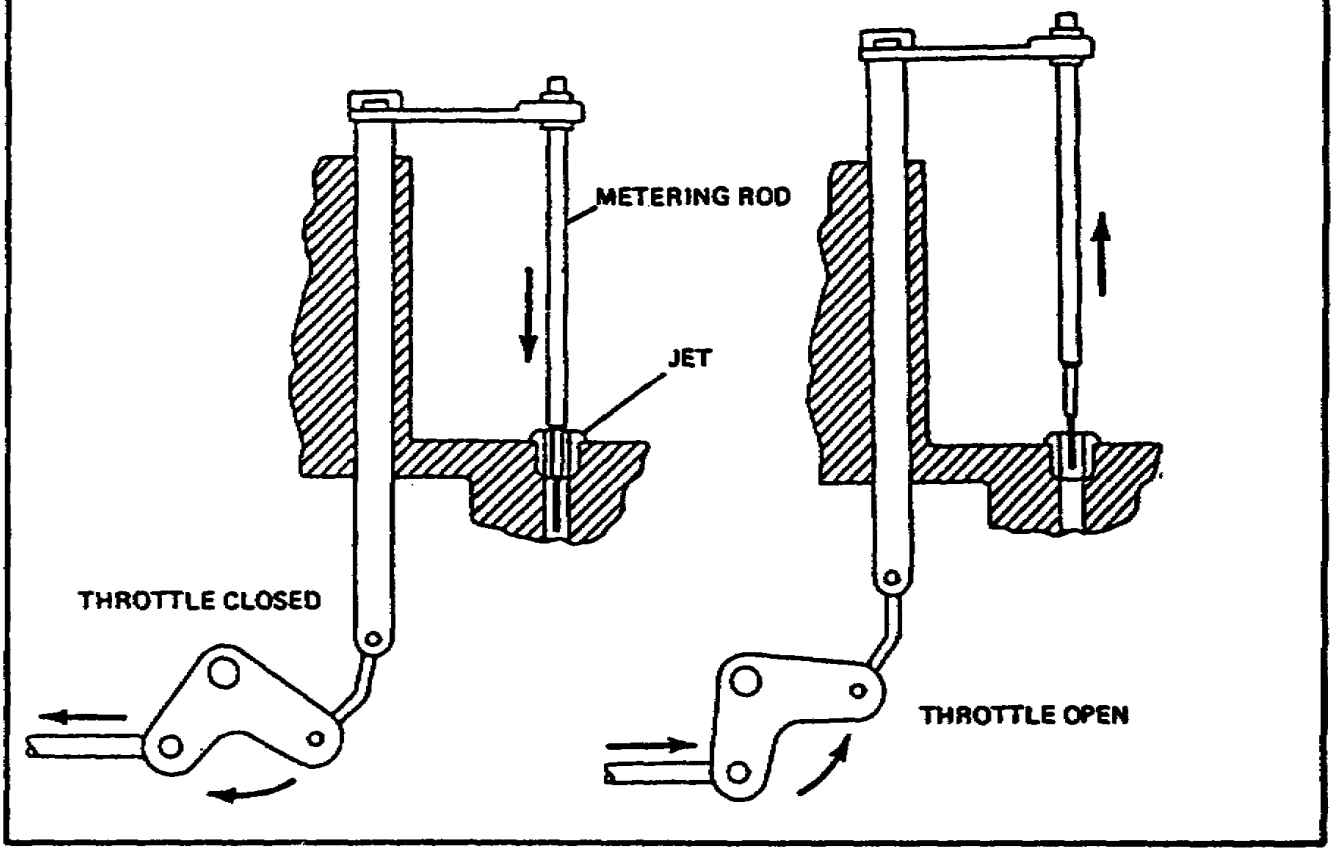
(b) *Vacuum-Operated Metering Rod* (figure 18). The vacuum-operated metering rod uses a rod with a diameter that gets progressively larger in steps from its end. The vacuum piston operates the metering rod. When the engine load is light and manifold vacuum is high, the piston pushes the metering rod into the jet against spring pressure, restricting the flow to the discharge tube. When the load demand increases, the manifold vacuum decreases, causing the piston spring to lift the metering rod out of the jet, progressively increasing the fuel flow to the discharge tube.

FIGURE 18. VACUUM-OPERATED OPERATED METERING ROD.



(c) *Mechanically-Operated Metering Rod* (figure 19 on the following page). The mechanically operated metering rod works by the same principles as the vacuum-operated metering rod, except that it is operated by linkage from the throttle valve. The linkage is calibrated so that the metering rod regulates the fuel perfectly for each throttle position.

FIGURE 19. MECHANICALLY OPERATED METERING ROD.



d. *Accelerator Pump Circuit.*

(1) *Purpose.* When the throttle valve is suddenly opened, there is a corresponding sudden increase in the speed of the airflow through the carburetor. Because the air is lighter than the gasoline, it will accelerate quicker, causing a very lean mixture to reach the engine for a brief period. This would result in a severe lag in engine performance if it were not for the accelerator pump circuit. Its job is to inject a measured charge of gasoline into the carburetor throat whenever the throttle valve is opened.

(2) *Operation.* The accelerator pump circuit consists of a pump that is operated by linkage directly from the throttle valve. There are passageways that connect the pump to the float bowl and pump discharge nozzle. Two check valves in the system control the direction of gasoline flow. Operation is as follows:

(a) The pump is pushed down in the pump chamber as the throttle valve is opened, forcing gasoline through the outlet passageway.

(b) The inlet check valve will seat, keeping gasoline from being pumped back to the float bowl.

(c) The outlet check ball will be forced off its seat, allowing the gasoline to pass to the pump discharge nozzle where it will be discharged into the throat.

(d) The pump is raised in the chamber when the throttle valve is closed, causing the outlet check ball to seat, blocking the passageway.

(e) The inlet check ball is pulled off its seat and gasoline is pulled into the chamber from the float bowl.

(f) The pump chamber is filled with gasoline and ready to discharge whenever the throttle valve is opened.

(3) *Diaphragm Pump* (figure 20 on the following page). The diaphragm-type pump system works similarly to the piston-type, with the exception of the pump design which includes a flat rubber diaphragm. By flexing this diaphragm, a pressure differential is created that results in pump action.

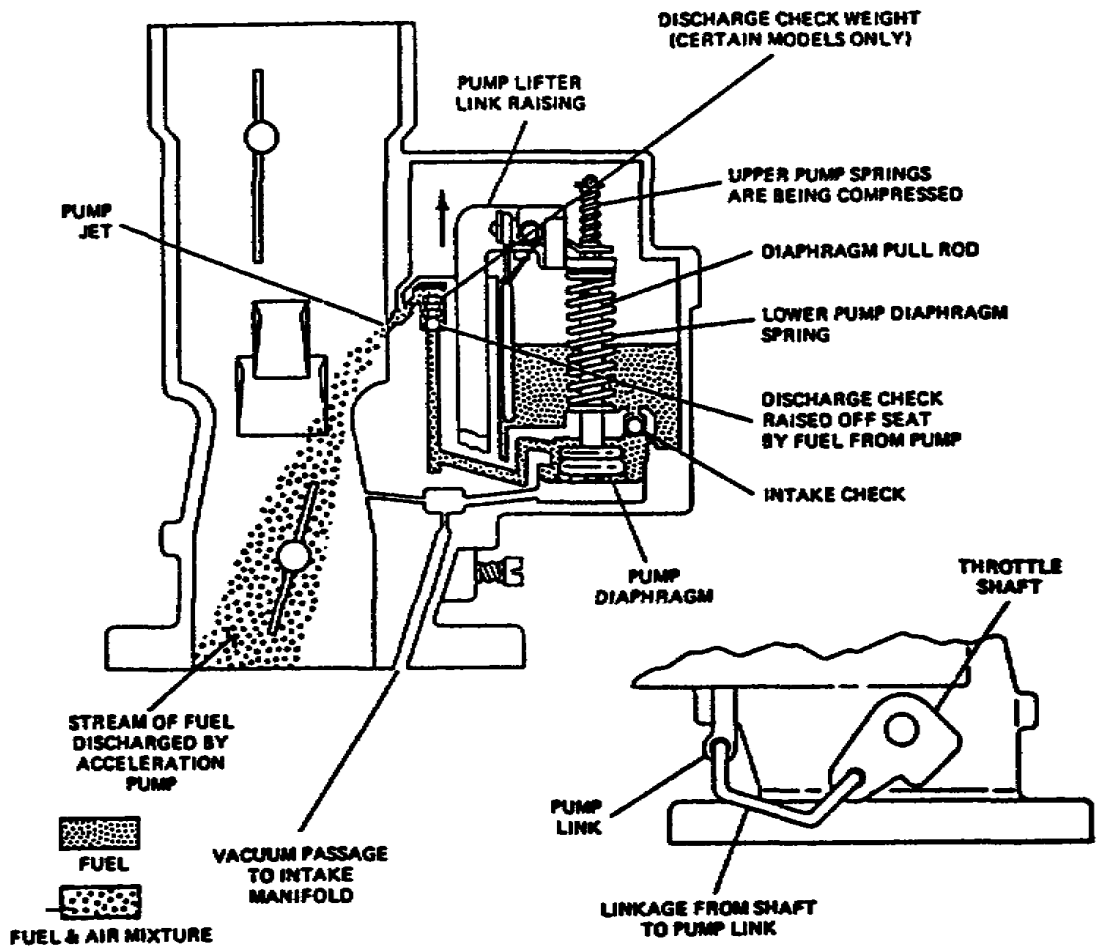
(4) *Controlling Pump Discharge.* The linkage between the accelerator pump and the throttle cannot be solid. If it were, the pump would act as a damper, not allowing the throttle to be opened and closed readily. The linkage usually activates the pump through a slotted shaft or something similar. When the throttle is closed, the pump is held up by its linkage. When the throttle is opened, the pump is activated by being pushed down by a spring, called a duration spring.

The tension of the duration spring controls the length of time that the injection of fuel lasts. The spring is calibrated to specific applications. Too much spring pressure will cause fuel to be discharged too quickly, resulting in reduced fuel economy. Too little spring pressure will cause fuel to be discharged too slowly, resulting in engine hesitations.

e. *Choke System.*

(1) *Purpose.* When the engine is cold, the gasoline tends to condense into large drops in the

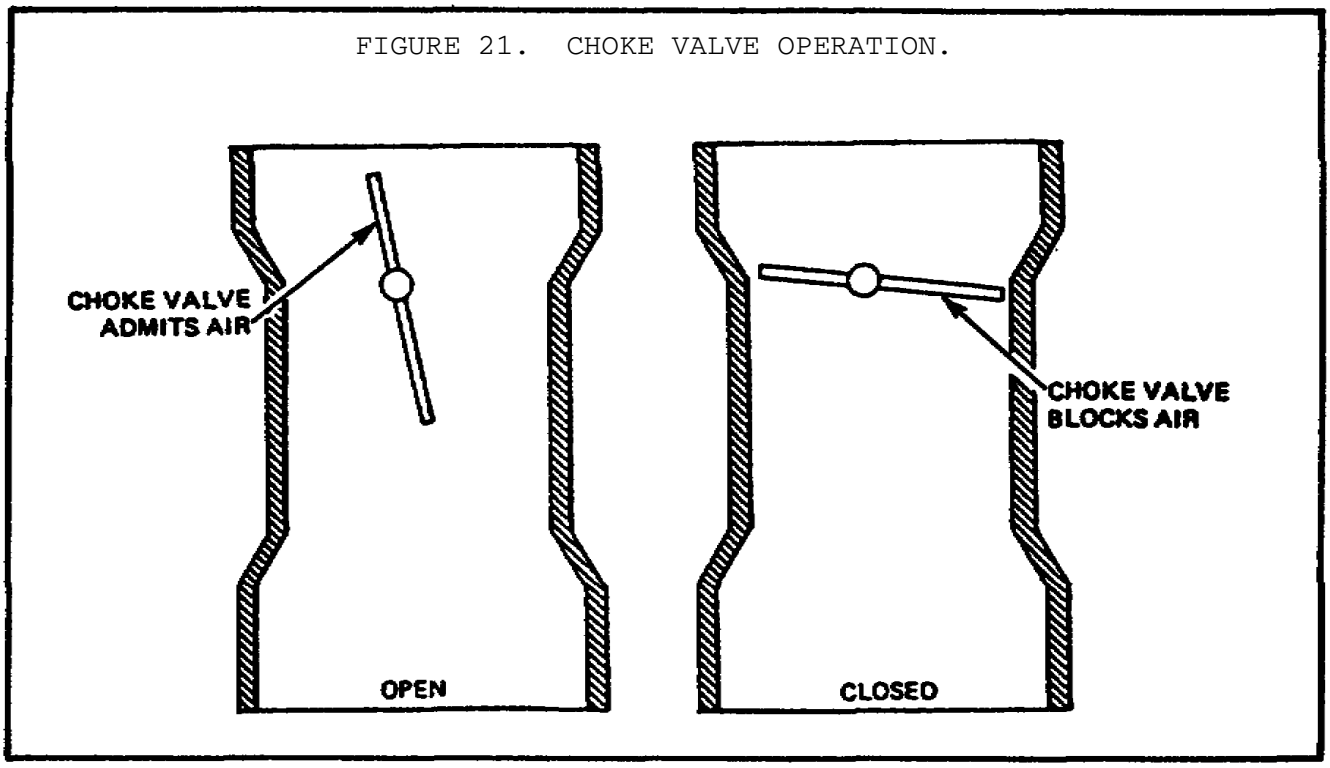
FIGURE 20. DIAPHRAGM ACCELERATOR PUMP.


DISCHARGE CHECK WEIGHT (CERTAIN MODELS ONLY)
PUMP LIFTER LINK RAISING
UPPER PUMP SPRINGS ARE BEING COMPRESSED
PUMP JET
DIAPHRAGM PULL ROD
LOWER PUMP DIAPHRAGM SPRING
DISCHARGE CHECK RAISED OFF SEAT BY FUEL FROM PUMP
INTAKE CHECK
PUMP DIAPHRAGM
THROTTLE SHAFT
STREAM OF FUEL DISCHARGED BY ACCELERATION PUMP
FUEL
FUEL & AIR MIXTURE
VACUUM PASSAGE TO INTAKE MANIFOLD
PUMP LINK
LINKAGE FROM SHAFT TO PUMP LINK

manifold rather than vaporizing. By supplying a richer mixture (8:1 to 9:1), there will be enough vapor to assure complete combustion. The carburetor is fitted with a choke system to provide this richer mixture. The choke system provides a very rich mixture to start the cold engine. It then gradually makes the mixture less rich as the engine reaches operating temperature.

(2) *Operation* (figure 21 on the following page). The choke system consists of a flat plate that restricts the throat above the venturi, but is located below the balance tube so that it has no affect on the pressure in the float bowl. This plate is called a choke valve, and, like the throttle valve, is mounted on a shaft to tilt it opened or closed.

FIGURE 21. CHOKE VALVE OPERATION.

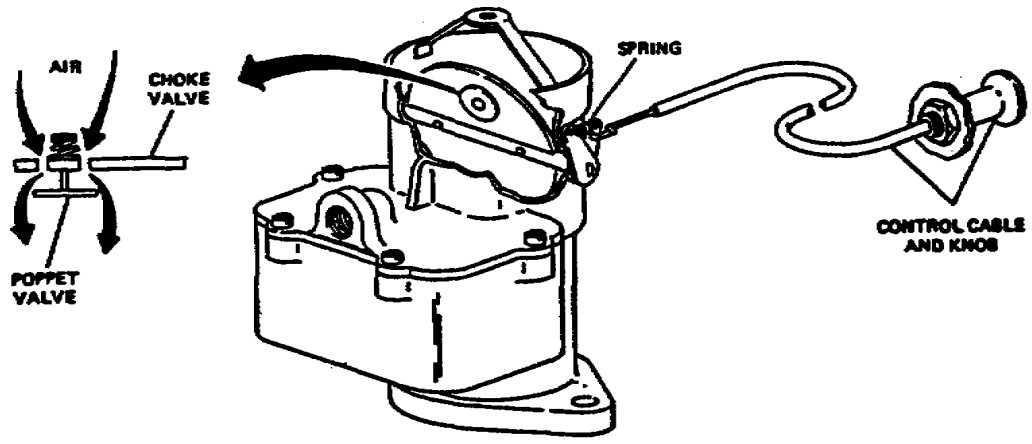


(3) *Manuel Choke System* (figure 22 on the following page). The manually operated choke used to be the most common method of controlling the choke valve. Due to emission regulations and the possible danger in use with catalytic converters, and to technological advances in automatic choke systems, manual choke systems are little used today. In a manual system, the choke valve is operated by a flexible cable that extends into the driver's compartment. As the control is pulled out, the choke valve will be closed so that the engine can be started. As the control is pushed back in, the position of the choke valve is adjusted to provide the proper mixture. The following are two features that are incorporated into manual choke systems to reduce the possibility of engine flooding by automatically admitting air into the engine:

(a) A spring-loaded poppet valve that is automatically pulled open by the force of the engine intake strokes.

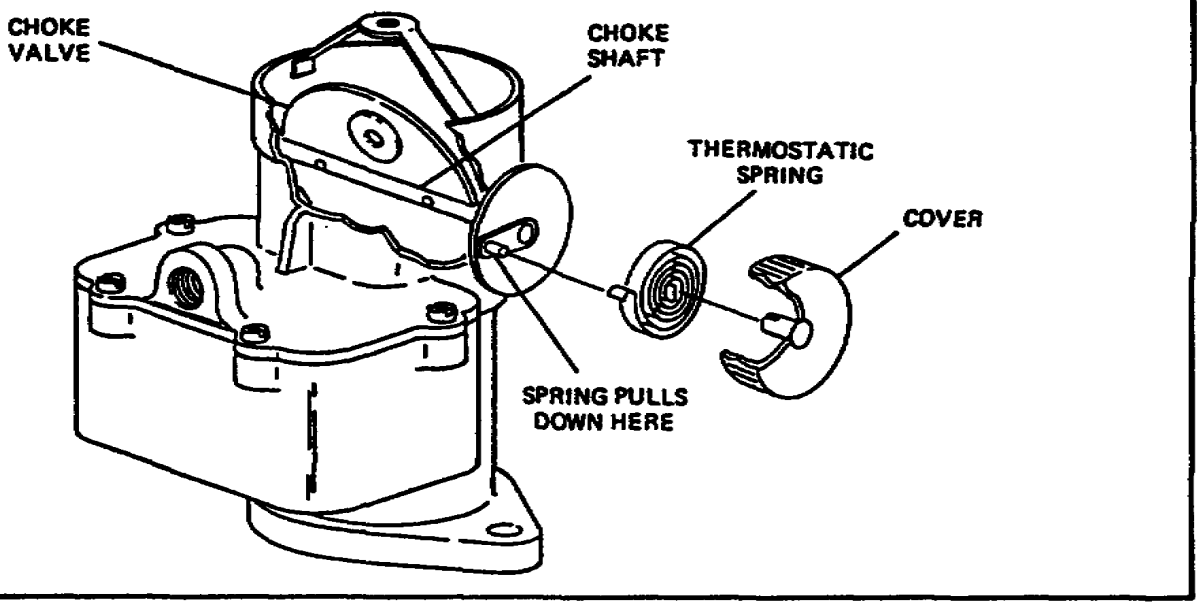
(b) A choke valve that is pivoted off center on its shaft. This will create a pressure differential between the two sides of the choke valve when it is subjected to the engine intake, causing it to be pulled open against the force of spring-loaded linkage.

FIGURE 22. MANUAL CHOKE SYSTEM.



(4) *Automatic Choke System* (figure 23). The automatic choke control system is centered around a thermostatic coil spring. The spring exerts pressure to hold the choke valve closed. Heat is applied to the coil after the engine is started. The heat causes the coil to expand, allowing the choke to open.

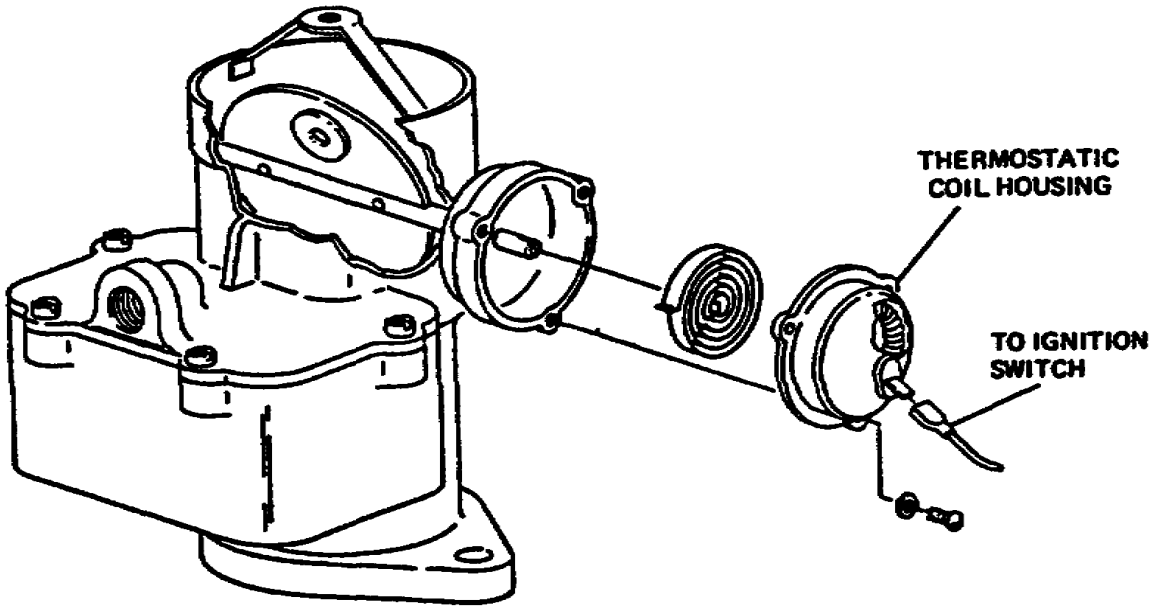
FIGURE 23. AUTOMATIC CHOKE SYSTEM.



(5) *Providing Automatic Choke Heat.* The four methods of providing controlled heat to the automatic choke thermostatic spring are:

(a) *Electricity* (figure 24). A large portion of the vehicles currently produced use an electric coil to heat the thermostatic coil spring. The heating coil is switched on with the ignition switch. Some systems employ a control unit that prevents power from reaching the electric coil until the engine compartment reaches a desired temperature.

FIGURE 24. ELECTRIC CHOKE.



(b) *Engine Coolant* (figure 25 on the following page). Another method of heating the thermostatic coil is to circulate engine coolant through a passage in the thermostat housing.

(c) *Intake Manifold Crossover* (figure 26 on the following page). One of the most popular methods of providing choke heat, until recent years, is to utilize exhaust heat. The usual way of doing this is to mount the choke mechanism containing the thermostatic coil in a molded well on the intake manifold over the crossover passage. The choke mechanism then operates the choke valve through linkage.

FIGURE 25. ENGINE COOLANT HEATED CHOKE.

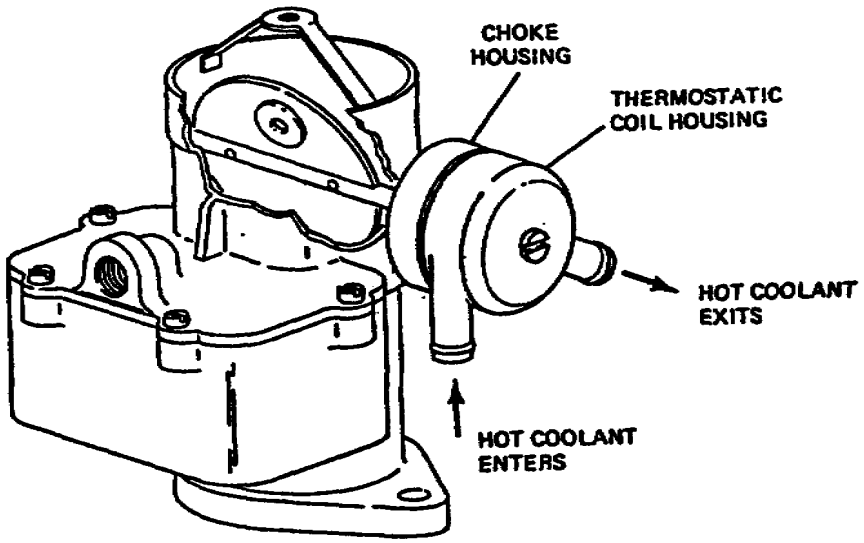
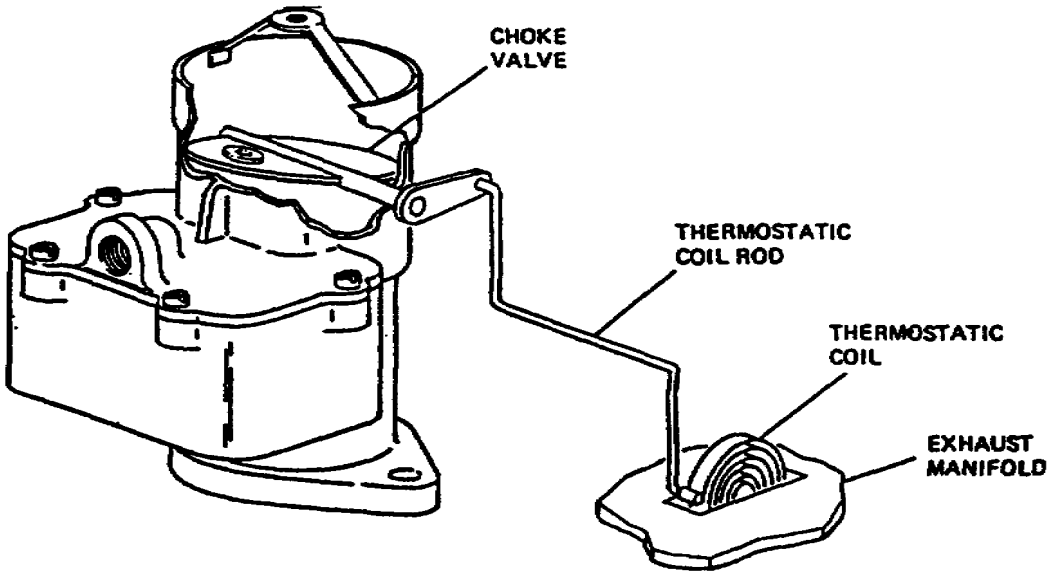
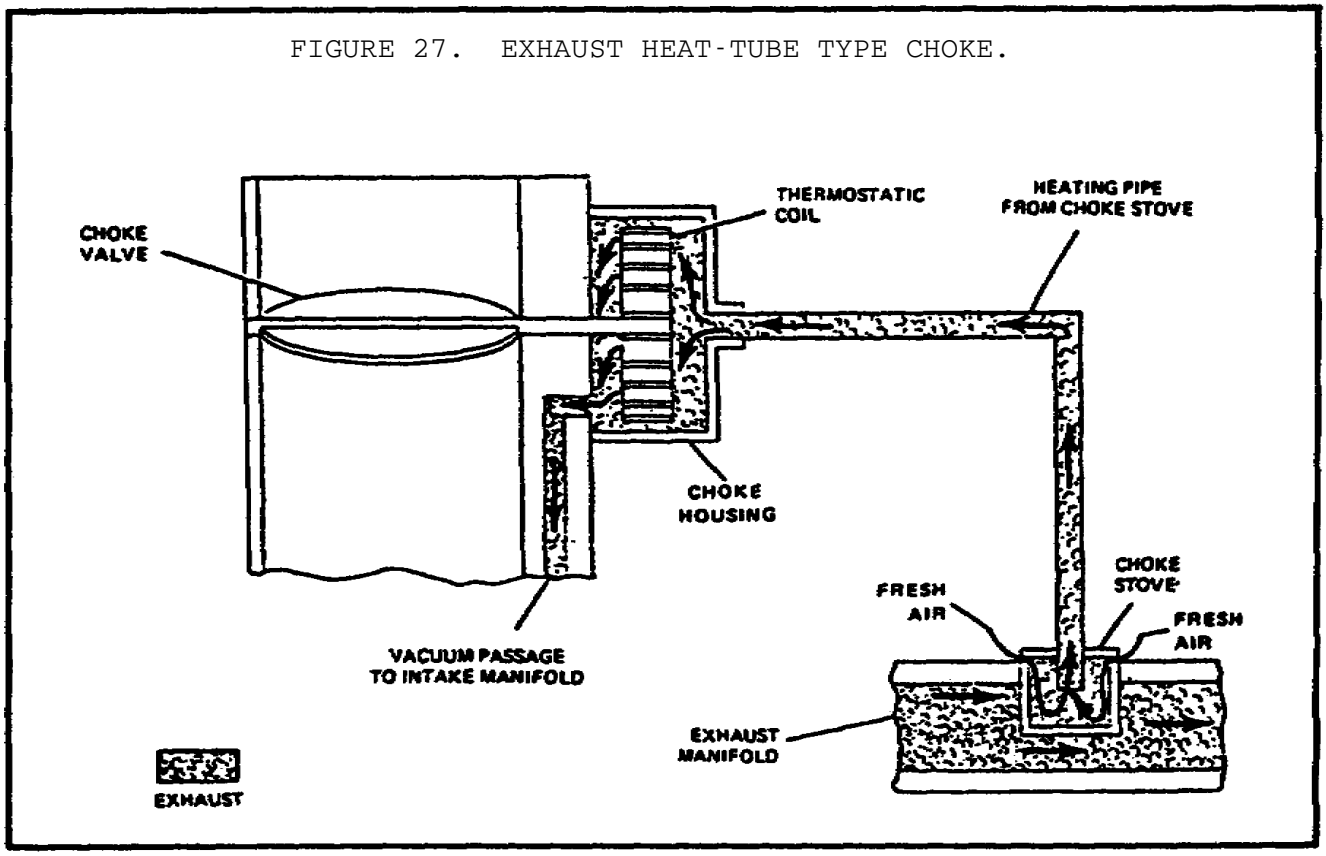


FIGURE 26. WELL-TYPE EXHAUST HEATED CHOKE.



(d) *Exhaust Manifold* (figure 27). This system has the choke mechanism mounted on the carburetor in a sealed housing. The choke housing is connected to a tube that runs through the exhaust manifold. This tube supplies heat to the choke mechanism. The choke housing also is connected internally to a manifold vacuum source. As the engine runs, the manifold vacuum draws air through the heat tube and the choke housing. The heat tube passes right through the exhaust manifold so that, as it takes in fresh air via the choke stove, it will pick up heat from the exhaust without sending any actual exhaust fumes to the choke mechanism. Heating of the fresh air entering the heat tube occurs in the choke stove.

FIGURE 27. EXHAUST HEAT-TUBE TYPE CHOKE.



(6) *Regulating Choke Valve Opening.* As with the manual choke system, a device must be incorporated that will open the choke a measured amount against the force of the thermostatic coil. The manifold vacuum usually is used to operate this choking device.

(a) *Choke Piston.* The choke piston can be integral to the carburetor, as can the passage that supplies vacuum to it. The vacuum passage is

situated on the side of the piston cylinder so that it will only pull the choke valve open the desired amount before the piston will cover the vacuum passage. This will block the passage, keeping the piston from moving any further.

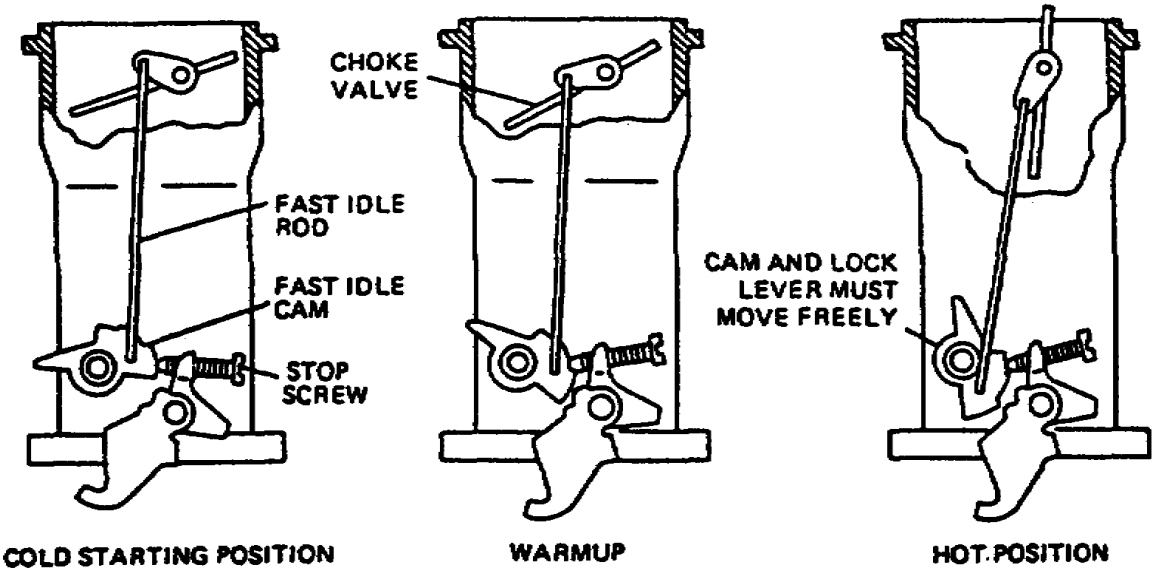
(b) *Choke Piston Integral with Choke Housing.* The choke piston system also may be integrated with the choke heating system. This is done by putting the choke piston into the choke housing. As the manifold vacuum pulls the piston open, controlled linkage around the piston allows the same vacuum source to pull in heated air for the choke.

(c) *Remote Choke Pulloff.* The remote choke pulloff is the most common configuration in current automotive design. It is made from either metal or plastic and uses a rubber diaphragm that pulls the choke open through linkage. The linkage is adjustable to obtain the proper choke valve opening. The lever on the choke shaft is slotted so it will not interfere with full choke valve opening.

(d) *Two-Stage Choke Pulloff.* A variation of the choke pulloff is the two-stage choke pulloff that has a spring-loaded telescoping pull rod. The choke valve, in the beginning, will be pulled open only partially. As the thermostatic coil heats and relaxes, it will be overcome by the pressure of the spring on the telescoping pull rod and the choke valve will open further. This design provides more precise control and is popular with emission-controlled vehicles.

(7) *Fast Idle Cam* (figure 28 on the following page). When the choke system is operating during warmup, the engine must run at a faster idle speed to improve driveability and prevent flooding. To accomplish this, the carburetor is fitted with a fast idle can operated by linkage from the choke. The fast idle cam operates by holding the throttle valve open. As the choke valve gradually opens, the can rotates, gradually reducing idle speed.

FIGURE 28. FAST IDLE CAM OPERATION.



(8) *Choke Unloader.* If for some reason the engine should flood when it is cold, a device is needed to open the choke so that air may be admitted to correct the condition. The device that accomplishes this is the choke unloader. The choke unloader usually consists of a projection from the fast idle can, which interacts with the throttle linkage. The operation is as follows:

(a) As the throttle valve is fully opened, the projection on the throttle lever contacts the projection on the fast idle can.

(b) The throttle lever, through the fast idle cam, then pulls the choke valve open a measured amount.

f. *Multiple-Venturi Carburetion.*

(1) *General.* A multiple-venturi or multiple-barrel carburetor is really a carburetor that has two or four separate single-venturi carburetors arranged in a cluster which in most cases share a common choke, float, and accelerator pumping system.

(2) *Purpose.* There are two reasons for using multiple-venturi carburetion:

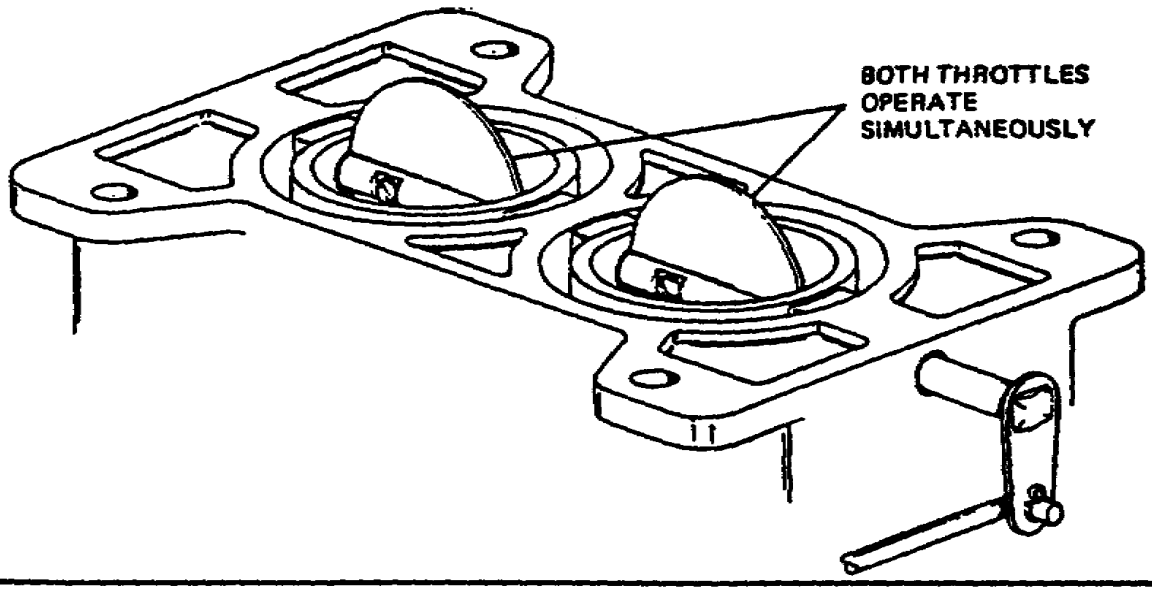
(a) The use of two separate carburetors, each feeding separate cylinders, can help to improve fuel distribution.

(b) The operating range of the engine can be increased, and driveability improved, if the throttle linkage is arranged to phase in the carburetor venturis gradually as the accelerator pedal is depressed.

There are two basic arrangements for the throttle linkage, depending on the purpose for having multiple-venturi carburetion. The linkage arrangements are discussed in the next two subparagraphs.

(3) *Fixed Throttle Linkage* (figure 29). Fixed throttle linkage is used mostly on two-venturi or two-barrel carburetors on engines containing six or more cylinders. This linkage arrangement is usually installed on an intake manifold so arranged that each venturi is feeding a selected half of the cylinders. The separation of the carburetor venturis within the intake manifold is usually to keep consecutively operating cylinders separated. Whenever two cylinders go through power strokes consecutively, the second of the two cylinders tends to have its fuel supply cut off. The fixed throttle linkage arrangement is a solid throttle shaft that operates both throttle valves simultaneously. There is an idle mixture screw on each side of the carburetor. The accelerator pump discharge nozzle usually contains two outlets.

FIGURE 29. TWO-BARREL CARBURETOR WITH FIXED LINKAGE.



(4) *Progressive Throttle Linkage.* Progressive throttle linkage is set up to open one throttle valve, or one set of throttle valves, at the beginning of the linkage travel and to begin to open the second throttle valve, or set of throttle valves, when the first is about two-thirds open. The geometry of the linkage is set up so that as the throttle reaches the full open point, all of the throttle valves will be wide open. The purpose is to provide a carburetor that will have a venturi small enough to provide good throttle response and fuel economy at low speed, yet large enough to allow the engine to perform well at high speed. The section of the carburetor that operates at low speed is called the primary section; the section that operates at high speed is celled the secondary section. It should be noted that the primary section of the carburetor works throughout the engine's operational range. It should also be noted that the secondary section of the carburetor has no choke, accelerator pump, low-speed, idle, or high-speed enrichment system. These systems are unnecessary in the secondary section of the carburetor for the following reasons:

(a) The secondary section of the carburetor is locked out so that its throttle valve(s) will not open when the choke system is operational on the primary side of the carburetor.

(b) At the speed that the engine is operating when the secondary section of the carburetor begins to operate, there will be no hesitation which would make an acceleration pump system necessary.

(c) Because the secondary section of the carburetor only operates at high speeds, it does not have to be jetted for two stages of operation and therefore will not require a high-speed enrichment system.

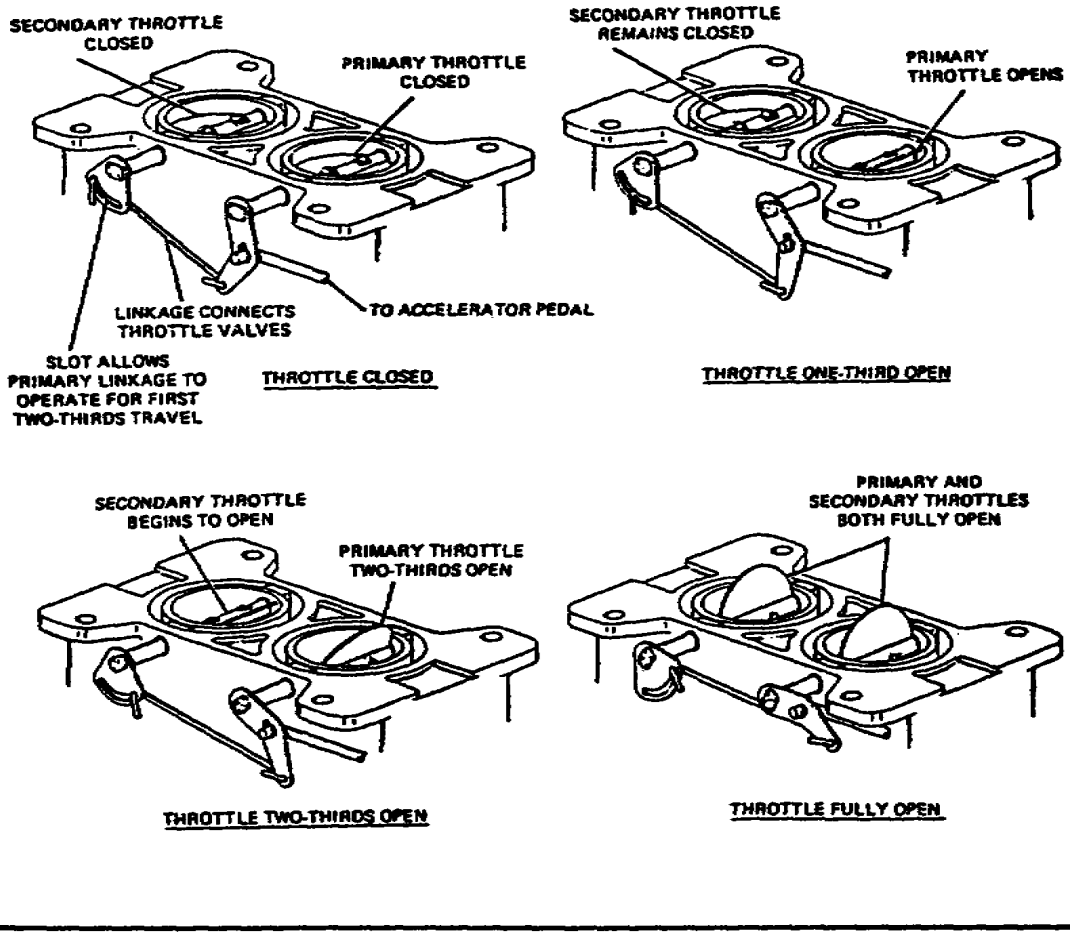
(d) Because the secondary section of the carburetor operates only at high speeds, a low-speed and idle system are unnecessary.

There are numerous devices and systems of linkage that are used to make the secondary section of the carburetor operate. They will be discussed in the following paragraphs.

(5) *Progressive Linkage Configurations.* A carburetor equipped with progressive linkage is designed so that the accelerator pedal directly operates the primary throttle valve(s). There are two ways in which the secondary throttle valve(s) are operated.

(a) Mechanically operated secondary throttle valve(s) (figure 30) are actuated by linkage from the primary throttle valve(s). The linkage is designed so that it will not be actuated until the primary throttle valve(s) are approximately two-thirds open. The operating arm on the primary throttle shaft is made to be approximately three times as long as the arm on the secondary throttle

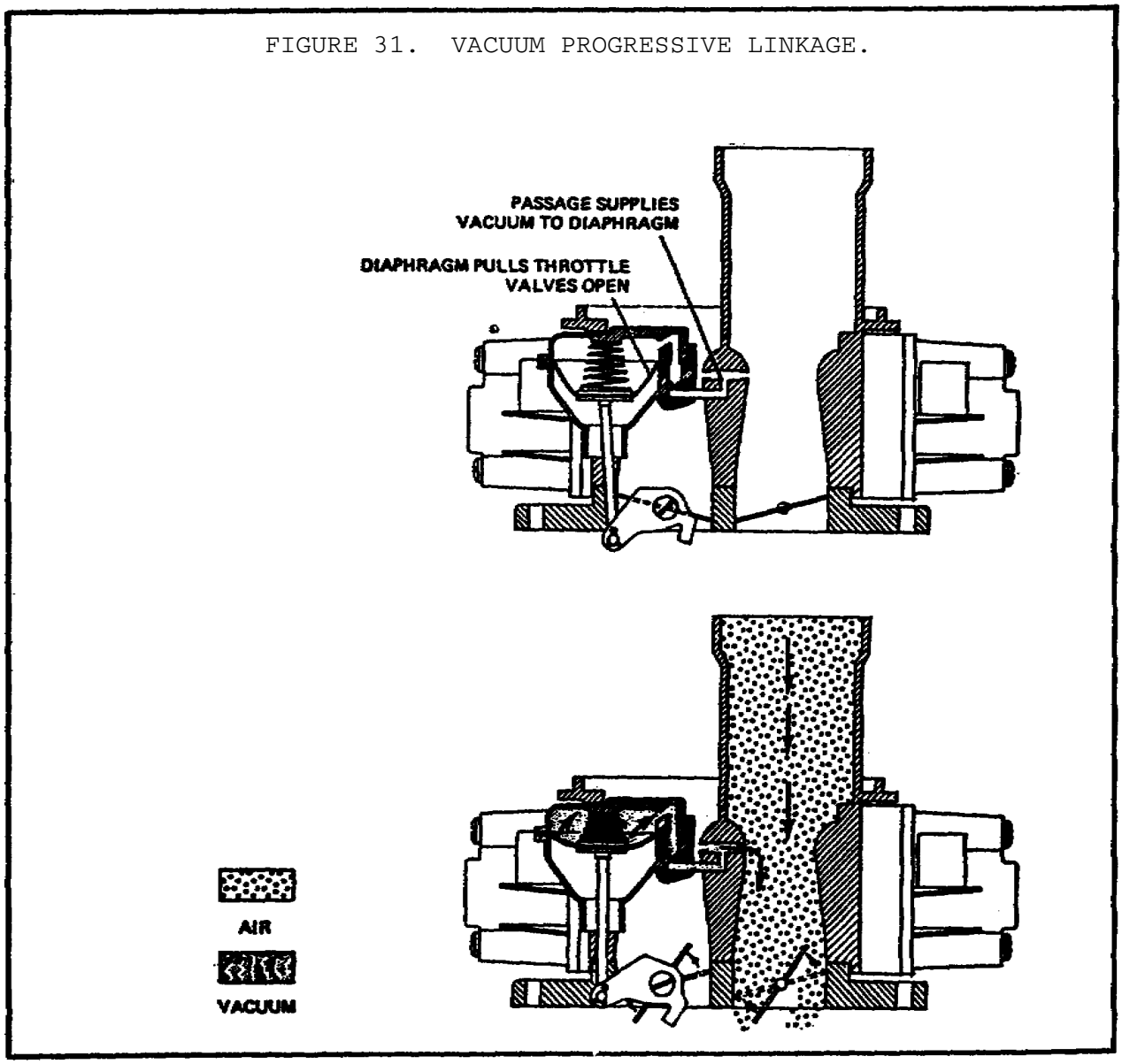
FIGURE 30. MECHANICAL PROGRESSIVE LINKAGE OPERATION.


SECONDARY THROTTLE CLOSED
PRIMARY THROTTLE CLOSED
LINKAGE CONNECTS THROTTLE VALVES
TO ACCELERATOR PEDAL
SLOT ALLOWS PRIMARY LINKAGE TO OPERATE FOR FIRST TWO-THIRDS TRAVEL
THROTTLE CLOSED
SECONDARY THROTTLE REMAINS CLOSED
PRIMARY THROTTLE OPENS
THROTTLE ONE-THIRD OPEN
SECONDARY THROTTLE BEGINS TO OPEN
PRIMARY THROTTLE TWO-THIRDS OPEN
THROTTLE TWO-THIRDS OPEN
PRIMARY AND SECONDARY THROTTLES BOTH FULLY OPEN
THROTTLE FULLY OPEN

shaft, so that the secondary throttle valve(s) will open all the way during the final third of primary throttle valve opening. The operating arm on the secondary throttle shaft operates through a spring, so that it will not interfere with primary throttle operation when the choke lockout is engaged.

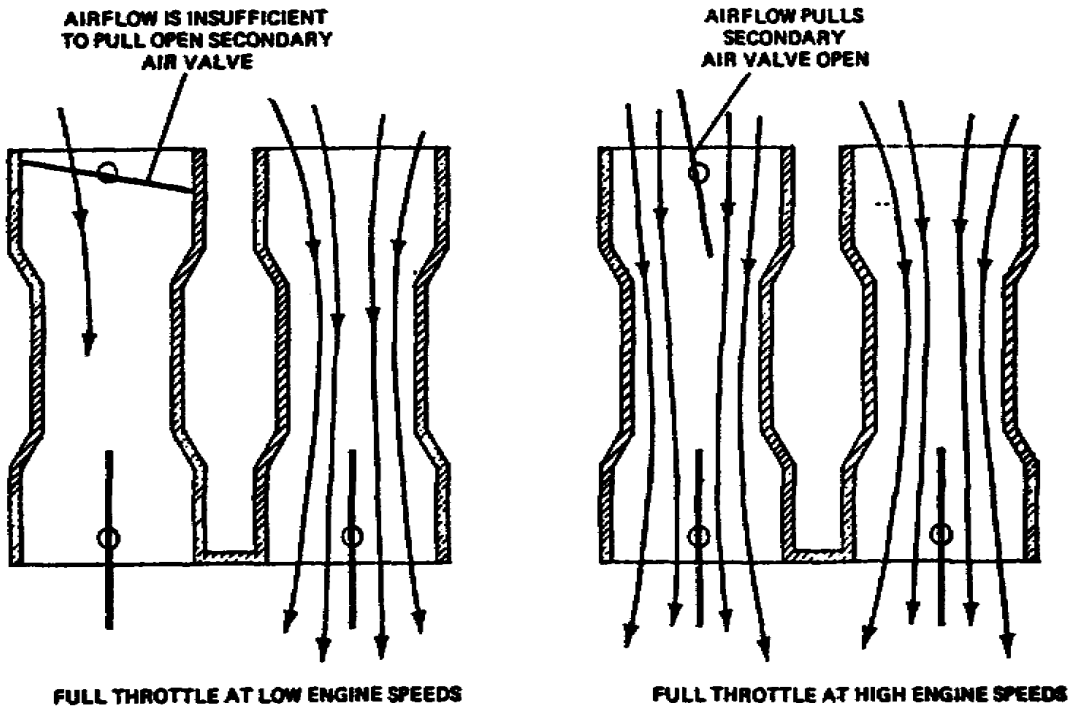
(b) Vacuum-operated secondary throttle valve(s) (figure 31) are actuated by a vacuum diaphragm whose vacuum source is the primary venturi. The principle of operation is that as engine speed increases, the vacuum in the primary venturi also increases causing the diaphragm to pull the secondary throttle valves open. There is linkage between the primary and secondary throttle valve(s) in relation to the primary throttle valves.

FIGURE 31. VACUUM PROGRESSIVE LINKAGE.



(6) *Secondary Air Valve* (figure 32). Carburetors equipped with mechanically operated secondary throttle valves are subject to engine hesitation if the throttle is suddenly opened all the way at low engine speeds, for the following reasons:

FIGURE 32. SECONDARY AIR VALVE OPERATION.

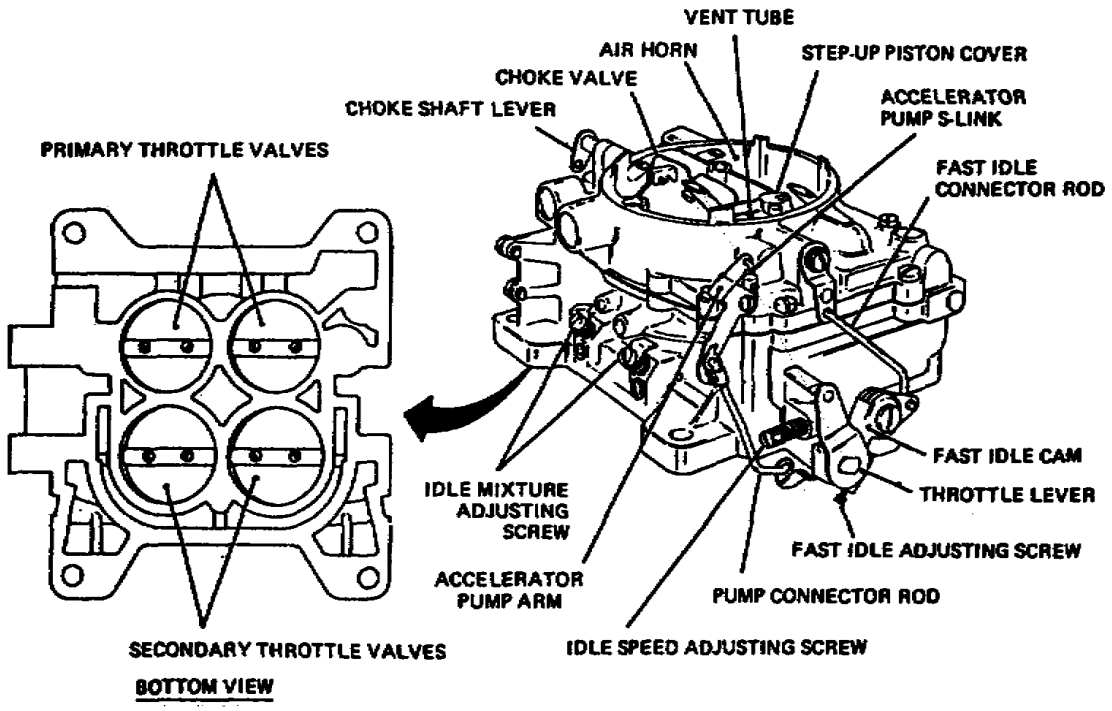

AIRFLOW IS INSUFFICIENT TO PULL OPEN SECONDARY AIR VALVE
AIRFLOW PULLS SECONDARY AIR VALVE OPEN
FULL THROTTLE AT LOW ENGINE SPEEDS
FULL THROTTLE AT HIGH ENGINE SPEEDS

(a) The opening of primary and secondary throttle valves provides too much venturi area for the engine to handle at low speed. It will not be able to move enough air through the venturis to properly draw fuel from the discharge tubes, causing a lean mixture.

(b) The secondary section of the carburetor is not equipped with an accelerator pump system and will cause an engine hesitation at low speed. To correct this deficiency, most carburetors with mechanical progressive linkage use a secondary air valve. A secondary air valve fits into the secondary throat and serves to restrict airflow through the secondary venturi(s) until the engine is at a high enough speed to use them correctly. The valve is actuated by a vacuum under it, which pulls it open against a spring force.

(7) *Four-Barrel Carburetor* (figure 33). The four-barrel or four-venturi carburetor consists of two primary venturis on a fixed throttle shaft that are progressively linked to two secondary venturis that are also on a fixed throttle shaft. The four-barrel carburetor is commonly used for V-8 engine configurations, for the following reasons:

FIGURE 33. TYPICAL FOUR-BARREL CARBURETOR.



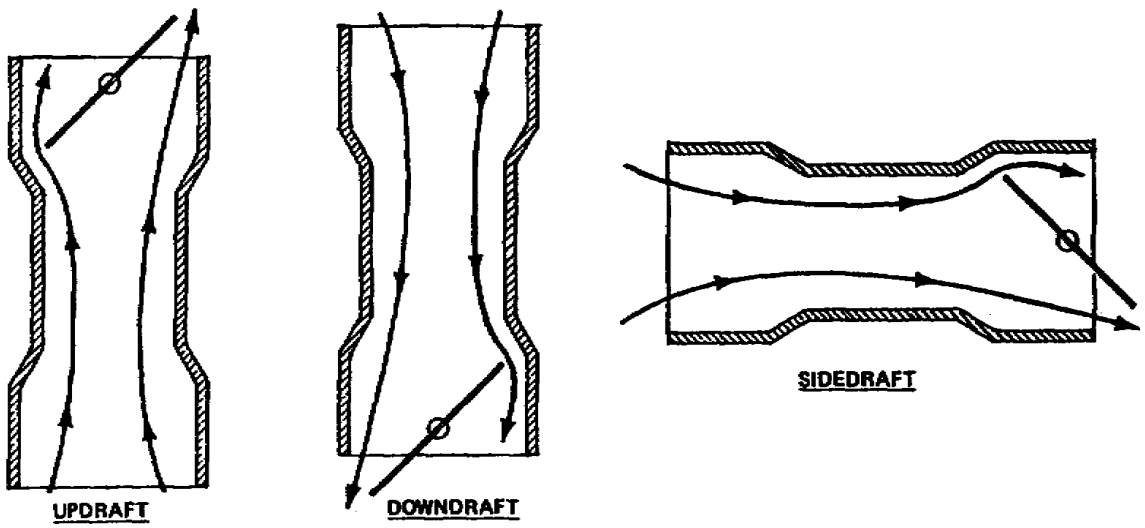
(a) The intake manifold may be divided to separate consecutive cylinders.

(b) The carburetor serves the engine better throughout the entire load and speed range.

g. *Updraft, Downdraft, and Sidedraft Carburetion* (figure 34 on the following page). Carburetors may be built so that the airflow in the throat is downward, upward, or sideways, as shown in figure 34.

h. *Primer System.* Some gasoline engines are fitted with a primer system to aid cold starting. The primer system consists of a hand pump that forces gasoline through a line to inject it at critical locations along the intake manifold. The system is not used very much in modern equipment.

FIGURE 34. UPDRAFT, DOWNDRAFT, AND SIDEDRAFT CARBURETORS.

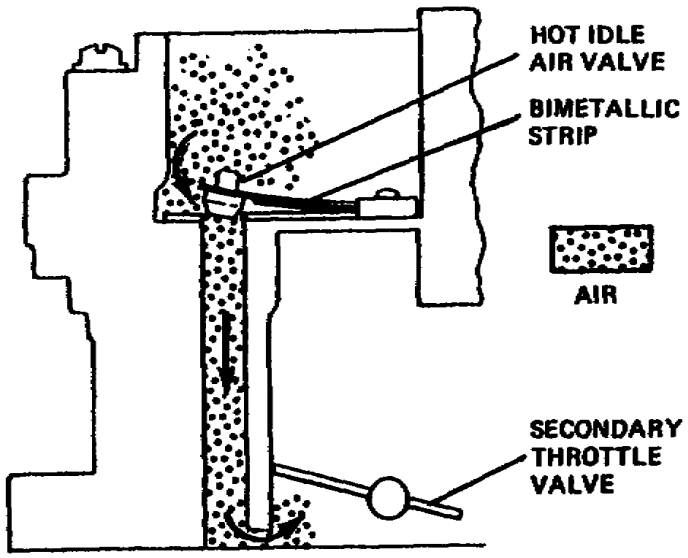


i. *Degasser System.* The degasser system is designed to shut off the supply of fuel to the idle circuit whenever there is high manifold vacuum, such as periods of deceleration, preventing large amounts of fuel from being drawn into the engine through the idle port. The degasser consists of a needle valve, a spring that holds the needle valve open, and a vacuum diaphragm that operates the needle valve through a fulcrum. The diaphragm is operated by a manifold vacuum. During periods of normal engine idle, the manifold vacuum is not high enough to operate the diaphragm and the needle valve remains open. During periods of deceleration, the manifold vacuum is high enough to cause the diaphragm to close the needle valve, shutting off the idle system. The needle valve can also be closed by pushing a button on the instrument panel to energize a solenoid, closing the needle valve. The purpose of this manual actuation device is to clear the idle circuit and manifold of unburned gases before the engine is turned off.

j. *Accessory Systems.* There are numerous devices that are used on carburetors to improve driveability and economy. Their application varies from vehicle to vehicle. The following paragraphs list the most common of these devices.

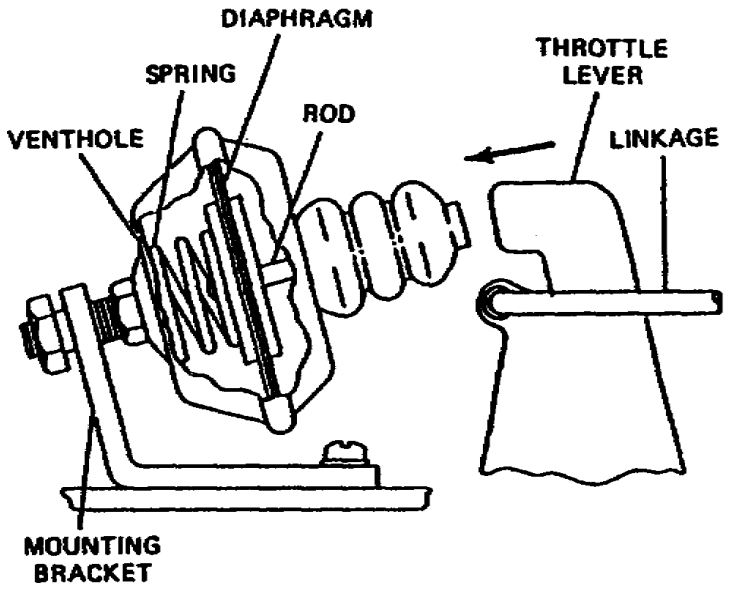
(1) *Hot Idle Compensator* (figure 35). The hot idle compensator is a thermostatically controlled valve that helps to prevent engine stalling when idling in very hot weather. Long periods of engine idle cause an excessive amount of vaporization of gasoline in the float bowl. These vapors will find their way into the carburetor throat and cause an overly rich mixture. The hot idle compensator consists of a bimetallic strip of metal which operates a valve that controls an air passage ending under the throttle valve. The bimetallic strip, which consists of two pieces of dissimilar metal with different expansion rates, will curl upwards as the temperature increases, opening the valve. This will, in turn, admit air under the throttle valve compensating for the overly rich mixture.

FIGURE 35. HOT IDLE COMPENSATOR.



(2) *Throttle Return Dashpot* (figure 36 on the following page). The throttle return dashpot acts as a damper to keep the throttle from closing too quickly when the accelerator pedal is suddenly released. This is important to prevent stalling on cars equipped with automatic transmissions. The throttle lever contacts the dashpot rod just before the throttle valves close. This will, in turn, push in on the diaphragm. The diaphragm slows the closing of the throttle because it must exhaust the air from the chamber through a tiny venthole. When

FIGURE 36. THROTTLE RETURN DASHPOT.

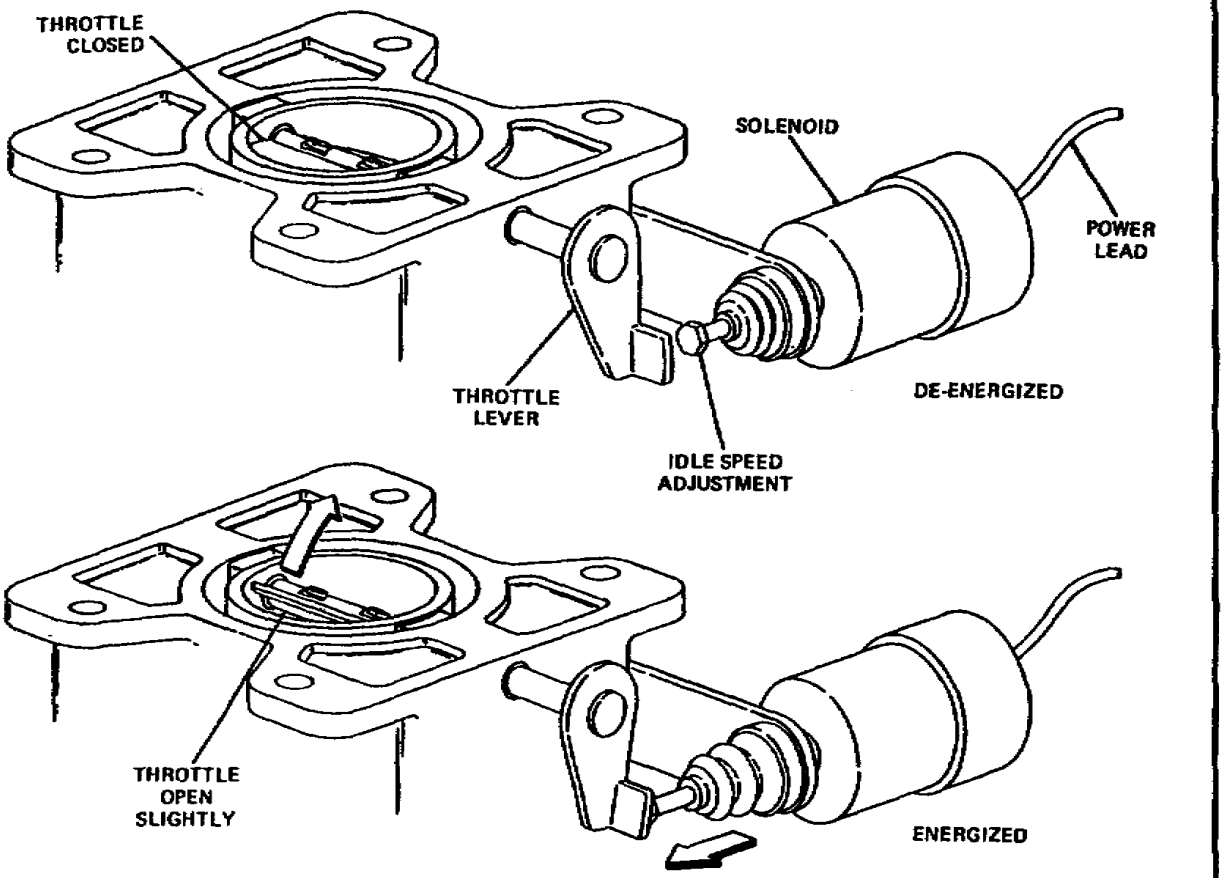


the throttle opens again, the dashpot spring pushes the diaphragm back into operating position, drawing air into the chamber.

(3) *Antidiesel Solenoid* (figure 37 on the following page). The antidiesel solenoid controls the throttle opening at engine idle to prevent dieseling. Engine dieseling is a condition that causes the engine to continue running after the ignition switch is turned off. It is a particular problem with emission controlled vehicles due to higher operating temperatures, higher idle speeds, leaner fuel mixtures, and lower octane gasoline. The solenoid is energized when the ignition switch is turned on, causing the plunger to open the throttle to idle speed position. The plunger length is adjustable so that the idle speed can be adjusted. When the ignition switch is turned off, the solenoid is deenergized and the throttle closes tightly, cutting off the air-fuel mixture. This will keep the engine from dieseling.

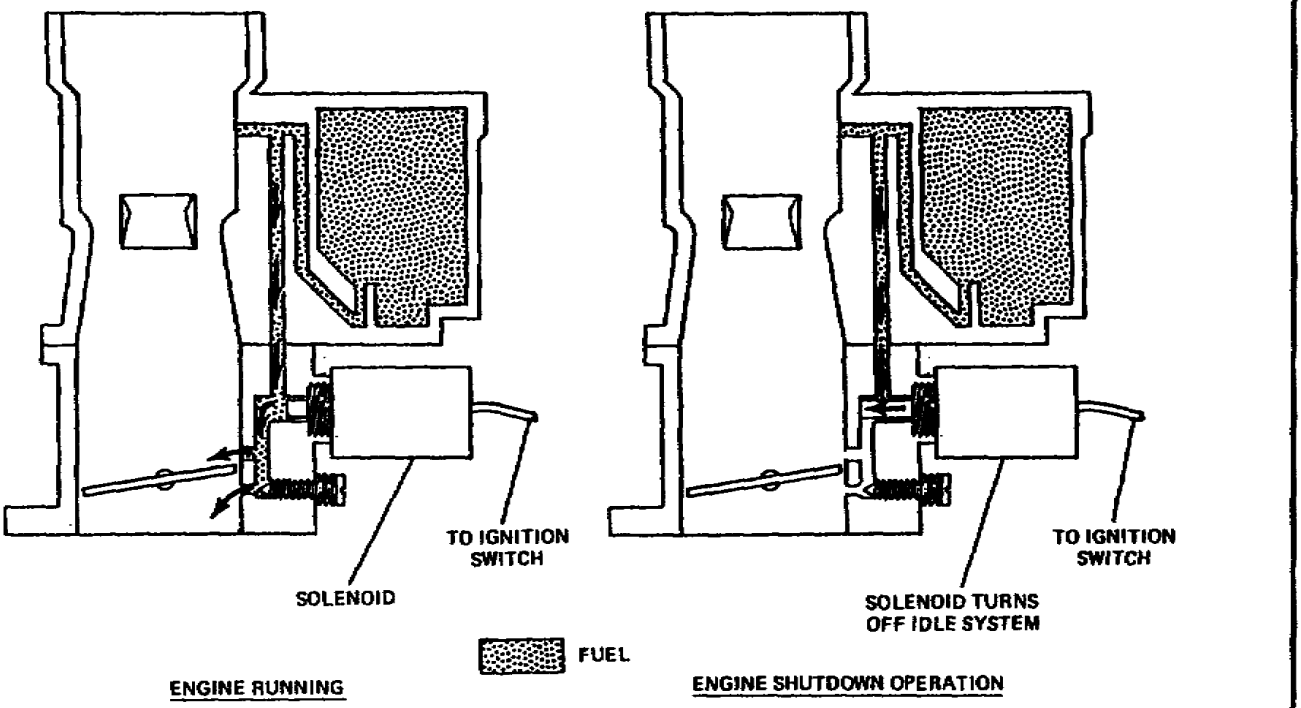
(4) *Air-Conditioning Solenoid* (figure 37). The air-conditioning solenoid is used on some engines to boost engine idle speed whenever the air-conditioner compressor is running. This compensates for the load placed on the engine, thus preventing stalling. Its operation is similar to the antidiesel solenoid described above.

FIGURE 37. ANTIDIESEL/AIR-CONDITIONING SOLENOID OPERATION.



(5) *Idle Solenoid System* (figure 38 on the following page). The idle solenoid system serves the same purpose as the degasser system. The system uses a solenoid whose operation is similar to the ones used in the two preceding paragraphs. The solenoid operates a needle valve that opens and closes the carburetor idle port. The needle valve is in a normally closed position. The solenoid is activated when the ignition switch is turned on, opening the needle valve. The purpose of shutting off the idle system with the engine is to help eliminate engine dieseling. A sensing switch is located in the intake manifold to shut off the idle system whenever manifold vacuum is excessively high, to prevent excess amounts of fuel from being sucked in through the idle port during deceleration.

FIGURE 38. IDLE SOLENOID SYSTEM.



(6) *Heated Air Intake System.* Most later model vehicles are fitted with a heated air intake system to provide the best performance in all temperatures with leaner fuel mixtures. The heated air intake system uses a damper door in the air filter snorkel to select either cold fresh air intake or heated air that is ducted from a heat stove on the exhaust manifold. The damper door is moved by a diaphragm that operates by manifold vacuum. The position of the damper door is determined by a temperature sensor. The system will keep the temperature of the intake air at about 100° to 115° F. Operation is as follows:

(a) When inlet air temperature is below 100°, the temperature sensor will allow full vacuum to flow to the operating diaphragm, pulling the damper door to the heated air position.

(b) When the inlet air is over 115°, the temperature sensor will bleed manifold vacuum off into the atmosphere. This will cause the diaphragm spring to push the damper door into the unheated fresh air position.

(c) The temperature sensor will at times bleed off only a portion of vacuum, causing the damper door to remain between the hot and cold position. This will regulate the temperature by providing a blend of hot and cold air.

(d) Whenever the engine is heavily accelerated, the manifold vacuum will drop and the damper door will move to the fresh air intake position.

11. Conclusion

This task covered the principles, construction and function of gasoline fuel systems, and completes lesson one. In lesson two, the function and construction of diesel fuel systems will be covered beginning with a discussion on the characteristics of diesel fuel. Before proceeding to lesson two, however, test your knowledge of lesson one by completing the practical exercise that follows.

PRACTICAL EXERCISE 1

1. Instructions

On a plain piece of paper, respond to the requirements listed below.

2. First Requirement

Answer these questions regarding the characteristics of gasoline.

a. Gasoline is the most popular petroleum based engine fuel. Gasoline contains two elements in such proportion that they will burn freely in air and liberate heat energy. What is the name of these two elements?

b. There are three major characteristics of gasoline that affect engine operation, one of which is volatility. Name the remaining two characteristics.

c. When fuel that is not vaporized leaks past the piston rings and seeps into the crankcase, it is commonly referred to as _____.

d. Describe how an engine will function when the fuel is not distributed evenly to all cylinders?

e. What is added to gasoline that mixes with the moisture and acts as antifreeze to prevent freezing?

f. The normal combustion process in the combustion chamber goes through three stages the first of which is the formation of the nucleus of flame. What are the remaining two stages?

g. During what stage, in the combustion process, will detonation take place.

h. The ability of a fuel to resist detonation is measured by its _____.

i. What is the compound that is added to gasoline to raise its octane rating?

j. Explain how preignition happens during compression within an engine.

3. Second Requirement

Answer the following question dealing with the principles, construction, and function of gasoline fuel systems.

a. What is installed inside a gas tank to prevent fuel from sloshing and to reinforce the overall strength of the tank?

b. Name the part of the fuel tank that is designed to prevent fuel from being spilled into the passenger, engine, or cargo compartment.

c. What type of fuel filter is periodically replaced and has a filter body that acts as a fuel sediment bowl?

d. The purpose of a fuel pump is to move fuel from one fuel system component and deliver it to another fuel system component. What are these two components?

e. What type of fuel pump is most commonly used for gasoline engine applications?

f. The fuel system component that helps to keep the vaporized fuel mixture from condensing before it reaches the combustion chamber is known as _____.

g. What form of intake design provides optimum performance for a given engine speed range by varying the length of the intake passages?

h. Name the two types of air filters presently in automotive use?

i. Briefly describe carburetion venturi effect.

j. What is the carburetor component that is used to regulate the speed and power output of the engine?

k. What is the effect on engine performance of too high a carburetor float level?

l. One of the two operating systems of the carburetor is the high-speed and high-speed enrichment circuit. What is the name of the other carburetor operating system?

m. The high-speed and high-speed enrichment circuit contains a component that is vacuum operated and provides an extra supply of fuel to the discharge nozzle. What is the name of this component?

n. Briefly describe the operation of the float circuit.

o. If for some reason the engine should flood when it is cold, a device is needed to open the choke so that air may be admitted to correct the condition. Name the carburetor component that performs this function.

p. A carburetor equipped with progressive throttle linkage is designed so that the accelerator pedal directly operates the primary throttle valves. What are the two ways in which the secondary throttle valves are operated?

q. Name the carburetor accessory component that is a thermostatically controlled valve which helps to prevent engine stalling when idling in very hot weather.

LESSON 1. PRACTICAL EXERCISE - ANSWERS

1. First Requirement

a. (1) Carbon

(2) Hydrogen

b. (1) Purity

(2) Antiknock quality (octane rating)

c. Crankcase dilution.

d. The engine will run unevenly and power output will decrease.

e. Deicing agents.

f. (1) Hatching out

(2) Propagation

g. The third stage (propagation).

h. Octane rating.

i. Tetraethyl lead.

j. Preignition is an igniting of the air-fuel mixture during compression before the spark occurs and is caused by some form of hot spot in the cylinder.

2. Second Requirement

a. Baffles.

b. Filler pipe.

c. Replaceable in-line fuel filter.

d. (1) Fuel tank

(2) Engine

e. Mechanical type fuel pump.

f. The intake manifold.

g. Ram induction.

h. (1) Dry-type air filter

(2) Wet-type air filter

i. Venturi effect is used by the carburetor to mix gasoline with air.

j. Throttle valve.

k. An overly rich mixture that reduces engine power output caused by spark plug fouling.

l. Idle and low-speed system.

m. Power jet.

n. The choke system consists of a flat plate that restricts the throat above the venturi but is located below the balance tube so that it has no affect on the pressure in the float bowl.

o. The choke unloader.

p. (1) Mechanical

(2) Vacuum

q. Hot idle compensator.

LESSON 2

FUNCTION AND CONSTRUCTION OF DIESEL FUEL SYSTEMS

TASK 1. Describe the characteristics of diesel fuel.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

The fuels used in modern high-speed diesel engines are derived from the heavier residues of the crude oil left over after the more volatile fuels, such as gasoline and kerosene, are removed during the refining process. The large, slow running diesel engines used in stationary or marine installations will burn almost any grade of heavy fuel oil. This contrasts with the smaller, high-speed diesel engines that require a fuel oil that is as light as kerosene.

Although diesel fuels are considered a residue of the refining process, their specification requirements are just as exacting as gasoline. In this lesson, the function and construction of diesel fuel systems will be discussed. The first task will describe the characteristics of diesel fuel; the second task will portray the principles, construction, and function of diesel fuel systems used in vehicles.

2. Characteristics of Diesel Fuels

a. *Cleanliness.* Probably the most necessary characteristic of diesel fuels is cleanliness. Any foreign material present in diesel fuel will certainly cause damage to the finely machined injector parts. Damage occurs in two ways:

(1) Particles of dirt cause scoring of the injector components.

(2) Moisture in the fuel will cause corrosion of the injector components.

Any damage to the fuel injectors will cause poor operation or render the engine inoperative. Controlling dirt and moisture content in diesel fuel is more difficult because it is heavier than gasoline. This causes foreign material to remain in suspension longer, so that sediment bowls do not work as well as with gasoline fuel systems.

b. *Viscosity.* The viscosity of a fluid is an indication of its resistance to flow. What this means is that a fluid with a high viscosity is heavier than a fluid with a low viscosity. The viscosity of diesel fuel must be low enough to flow freely at its lowest operational temperature, yet high enough to provide lubrication to the moving parts of the finely machined injectors. The fuel must also be sufficiently viscous so that leakage at the pump plungers and dribbling at the injectors will not occur. Viscosity also will determine the size of the fuel droplets which, in turn, govern the atomization and penetration qualities of the fuel injector spray.

c. *Ignition Quality.* The ignition quality of a fuel is its ability to ignite spontaneously under the conditions existing in the engine cylinder. The spontaneous-ignition point of a diesel fuel is a function of pressure, temperature, and time. Because it is difficult to reproduce the operating conditions of the fuel artificially outside the engine cylinder, a diesel engine operating under controlled conditions is used to determine the ignition quality of diesel fuel. The yardstick that is used to measure the ignition quality of a diesel fuel is the cetane number scale. The cetane number of a fuel is obtained by comparing it to the operation of a reference fuel. The reference fuel is a mixture of alpha-methyl-naphthalene, which has

virtually no spontaneous ignition qualities, and pure cetane, which has what are considered to be perfect spontaneous ignition qualities. The percentage of cetane is increased gradually in the reference fuel until the fuel matches the spontaneous ignition qualities of the fuel being tested. The cetane number then is established for the fuel being tested based on the percentage of cetane present in the reference mixture.

d. Diesel engines have a tendency to produce a knock that is particularly noticeable during times when the engine is under a light load. This knocking occurs due to a condition known as ignition delay or ignition lag. When the power stroke begins, the first molecules of fuel injected into the combustion chamber must first vaporize and superheat before ignition occurs. During this period, a quantity of unburned fuel builds up in the combustion chamber. When ignition occurs, the pressure increase causes the built-up fuel to ignite instantly. This causes a disproportionate increase in pressure, creating a distinct and audible knock. Increasing the compression ratio of a diesel engine will decrease ignition lag and the tendency to knock. This contrasts with a gasoline engine, whose tendency to knock will increase with an increase in compression ratio. Knocking in diesel engines is affected by factors other than compression ratio, such as the type of combustion chamber, airflow within the chamber, injector nozzle type, air and fuel temperature, and the cetane number of the fuel.

e. *Multifuel Engine Authorized Fuels.* Multifuel engines are four-stroke cycle diesel engines that will operate satisfactorily on a wide variety of fuels. The fuels are grouped accordingly:

(1) *Primary and Alternate I Fuels.* These fuels will operate the multifuel engine with no additives.

(2) *Alternate II Fuels.* These fuels generally require the addition of diesel fuel to operate the multifuel engine.

(3) *Emergency Fuels.* These fuels will operate the multifuel engine with the addition of diesel fuel; however, extended use of fuels from this group will cause eventual fouling of fuel injection

parts. It should be noted that there are no adjustments necessary to the engine when changing from one fuel to another.

f. *Fuel Density Compensator.* The multifuel engine operates on a variety of fuels, with a broad range of viscosities and heat values. These variations in the fuels affect engine output. Because it is unacceptable for the power output of the engine to vary with fuel changes, the multifuel engine is fitted with a device known as a fuel density compensator. The fuel density compensator is a device that serves to vary the quantity of fuel injected to the engine by regulating the full-load stop of the fuel pump. The characteristics of the fuels show that their heat values decrease almost inversely proportional to their viscosities. The fuel density compensator uses viscosity as the indicator for regulating fuel flow. Its operation is as follows:

(1) The fuel supply enters the compensator through the fuel pressure regulator, where the supply pressure is regulated to a constant 20 psi regardless of engine speed and load range.

(2) The pressure regulated fuel then passes through a series of two orifices. The two orifices, by offering greatly different resistances to flow, form a system that is sensitive to viscosity changes.

(a) The first orifice is annular, formed by the clearance between the servo piston and its cylinder. This orifice is sensitive to viscosity.

(b) The second orifice is formed by an adjustable needle valve and, unlike the first, is not viscosity sensitive.

(c) After the fuel passes through the two orifices, it leaves the compensator through an outlet port. From here, the fuel passes back to the pump.

(3) The higher the viscosity of the fuel, the more trouble it will have passing through the first orifice. Because of this, the fuel pressure under the servo piston will rise proportionally with viscosity. Because the second orifice is not viscosity sensitive, the pressure over the servo piston will remain fairly constant. This will

cause a pressure differential that increases proportionally with viscosity that, in turn, will cause the piston to seek a position in its bore that becomes higher as viscosity increases.

(4) The upward movement of the servo piston will move a wedge-shaped movable plate which will increase fuel delivery. A lower viscosity fuel will cause the piston to move downward causing the pump to decrease fuel delivery.

3. Conclusion

This task described the characteristics of diesel fuel. Having gained an understanding of diesel fuel, our attention in the next task will focus on the function and construction of diesel fuel systems.

LESSON 2

FUNCTION AND CONSTRUCTION OF DIESEL FUEL SYSTEMS

TASK 2. Describe the principles, construction, and function of diesel fuel systems.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

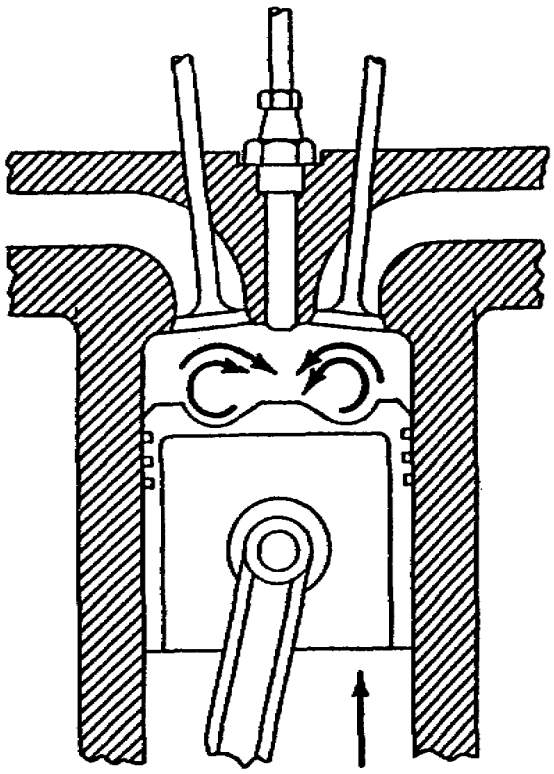
The fuel injected into the combustion chamber must be mixed thoroughly with the compressed air and distributed as evenly as possible throughout the chamber if the engine is to function at maximum efficiency and exhibit maximum driveability. The well-designed diesel engine uses a combustion chamber that is designed for the engine's intended usage.

This task illustrates the function of a diesel fuel system. It will describe the principles and construction for the following components of this system: injection systems, fuel supply pumps, governors, timing devices, and combustion chambers. The combustion chambers described in the following paragraphs are the most common, and cover virtually all of the designs used in current automotive practice.

2. Combustion Chamber Design

a. *Open Chamber* (figure 39). The open chamber is the simplest form of diesel chamber design. It is suitable only for slow-speed, four-stroke cycle engines, but is also used widely in two-stroke cycle diesel engines. In the open chamber, the fuel is injected directly into the space at the top of the cylinder. The combustion space, formed by the top of the piston and the cylinder head, usually is shaped to provide a swirling action of the air as the piston comes up on the compression stroke. There are no special pockets, cells, or passages to aid the mixing of the fuel and air. This type of chamber requires a higher injection pressure and a greater degree of fuel atomization than is required by other combustion chambers to obtain a comparable level of fuel mixing. This chamber design is very susceptible to ignition lag.

FIGURE 39. OPEN COMBUSTION CHAMBER.

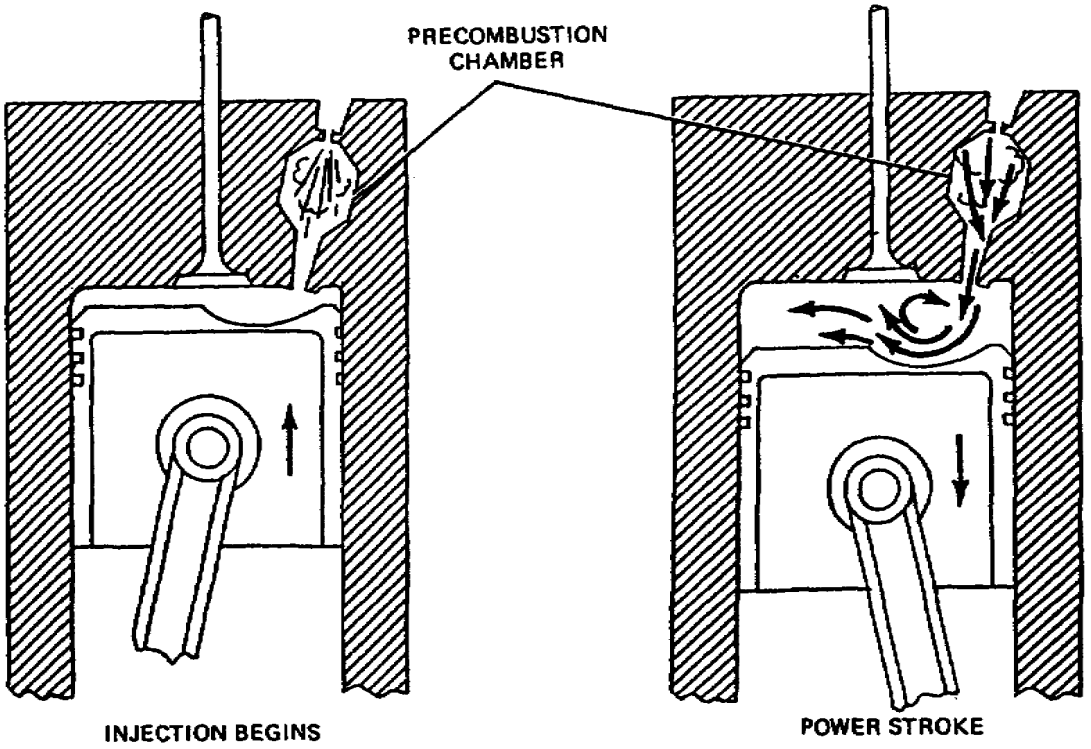


b. *Precombustion Chamber* (figure 40). The precombustion chamber is an auxiliary chamber at the top of the cylinder. It is connected to the main combustion chamber by a restricted throat or passage. The precombustion chamber conditions the fuel for final combustion in the cylinder. A hollowed out portion of the piston top causes turbulence in the main combustion chamber as the fuel enters from the precombustion chamber to aid in mixing with air. The following steps occur during the combustion process:

(1) During the compression stroke of the engine, air is forced into the precompression chamber and, because the air is compressed, it is hot. At the beginning of injection, the precombustion chamber contains a definite volume of air.

(2) As the injection begins, combustion starts in the precombustion chamber. The burning of the fuel, combined with the restricted passage to the main combustion chamber, creates a tremendous

FIGURE 40. PRECOMBUSTION CHAMBER.

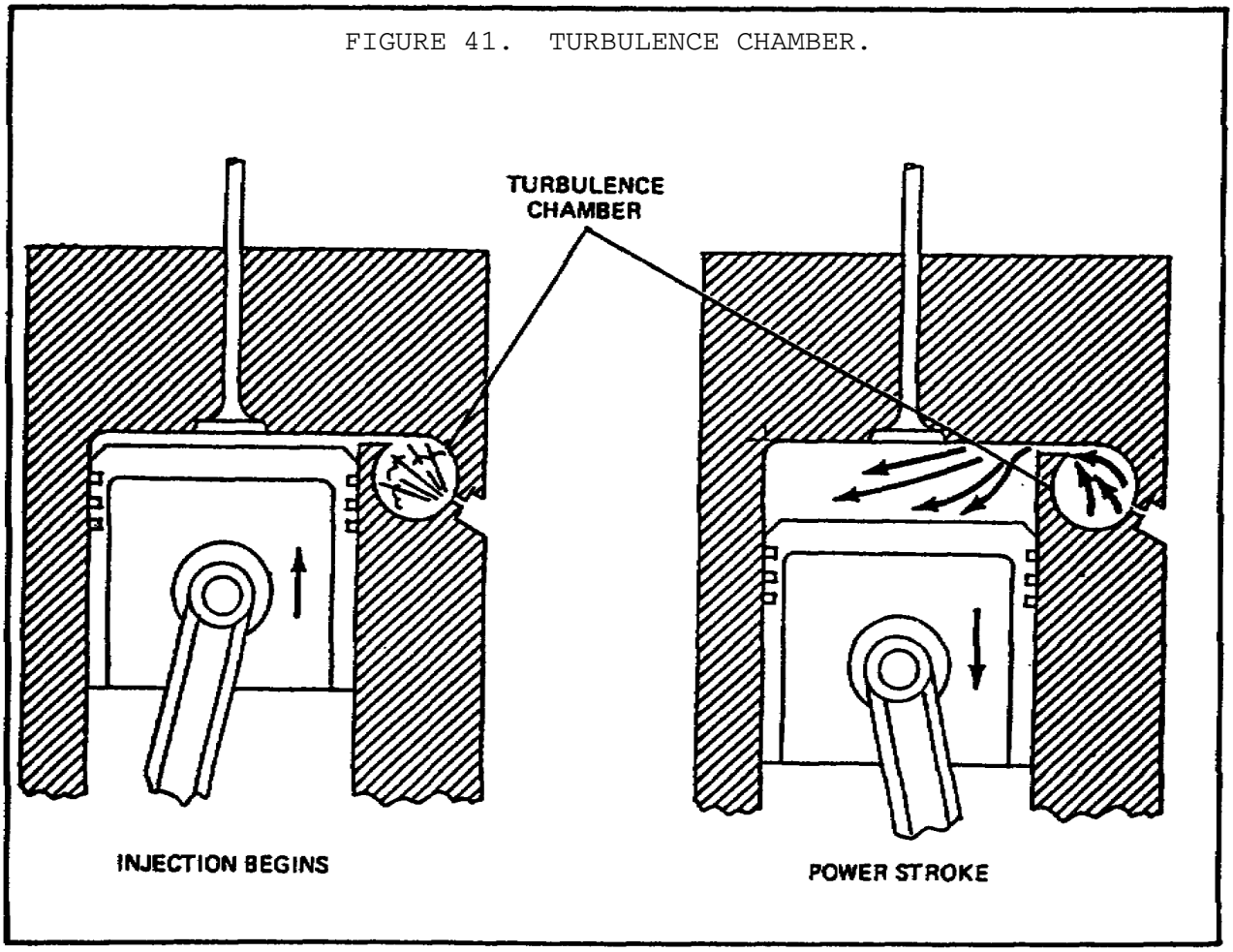


amount of pressure in the precombustion chamber. The pressure and the initial combustion cause a superheated fuel charge to enter the main combustion chamber at a tremendous velocity.

(3) The entering mixture hits the hollowed out piston top, creating turbulence in the chamber to ensure complete mixing of the fuel charge with the air. This mixing ensures even and complete combustion. This chamber design will provide satisfactory performance with low fuel injector pressures and coarse spray patterns because a large amount of vaporization takes place in the combustion chamber. This chamber is also not very susceptible to ignition lag, making it more suitable for high speed applications.

c. *Turbulence Chamber* (figure 41). The turbulence chamber is similar in appearance to the precombustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so that a high

FIGURE 41. TURBULENCE CHAMBER.



percentage of the air between the piston and the cylinder head is forced into the turbulence chamber during the compression stroke. The chamber usually is spherical, and the opening through which the air must pass becomes smaller as the piston reaches the top of the stroke, thereby increasing the velocity of the air in the chamber. This turbulence speed is approximately 50 times crankshaft speed. The fuel injection is timed to occur when the turbulence in the chamber is the greatest. This ensures a thorough mixing of the fuel and the air, with the result that the greater part of combustion takes place in the turbulence chamber itself. The pressure created by the expansion of the burning gases is the force that drives the piston downward on the power stroke.

d. *Spherical Combustion Chamber.* The spherical combustion chamber is designed principally for use in the multifuel engine. The chamber consists of a basic open-type chamber with a spherical-shaped relief in the top of the piston head. The chamber works in conjunction with a strategically positioned injector, and an intake port which produces a swirling effect on the intake air as it enters the chamber. Operation of the chamber is as follows:

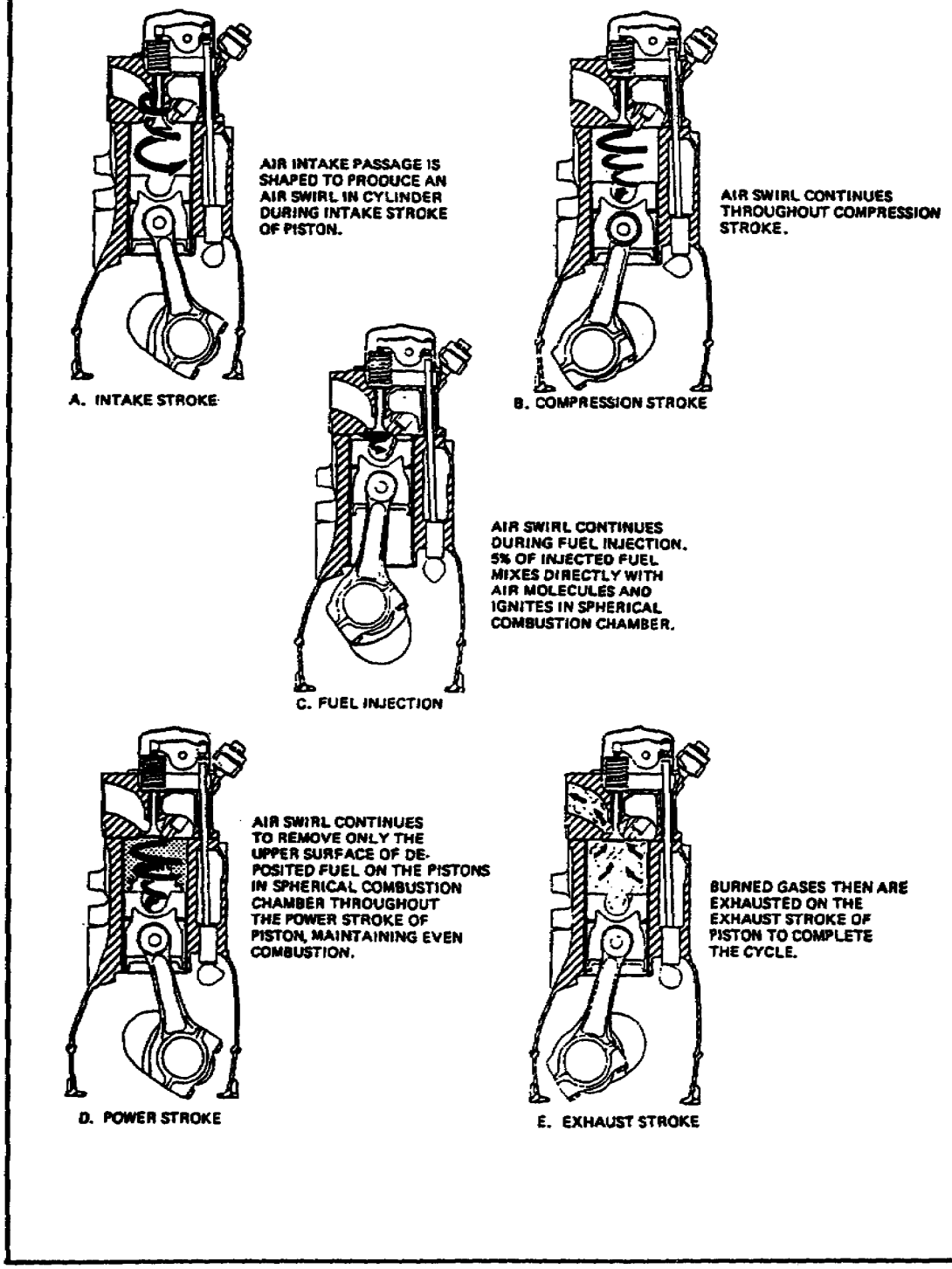
(1) As the air enters the combustion chamber, a swirl effect is introduced to it by the shape of the intake port (figure 42, view A, on the following page).

(2) During the compression stroke, the swirling motion of the air continues as the temperature in the chamber increases (figure 42, view B, on the following page).

(3) As the fuel is injected, approximately 95 percent of it is deposited on the head of the piston and the remainder mixes with the air in the spherical combustion chamber (figure 42, view C, on the following page).

(4) As combustion begins, the main portion of the fuel is swept off of the piston head by the high velocity swirl that was created by the intake and the compression strokes. As the fuel is swept off of the head, it burns through the power stroke, maintaining even combustion and eliminating detonation (figure 42, view D and E, on the following page).

FIGURE 42. SPHERICAL CHAMBER.


AIR INTAKE PASSAGE IS SHAPED TO PRODUCE AN AIR SWIRL IN CYLINDER DURING INTAKE STROKE OF PISTON.
A. INTAKE STROKE
AIR SWIRL CONTINUES THROUGHOUT COMPRESSION STROKE.
B. COMPRESSION STROKE
AIR SWIRL CONTINUES DURING FUEL INJECTION. 5% OF INJECTED FUEL MIXES DIRECTLY WITH AIR MOLECULES AND IGNITES IN SPHERICAL COMBUSTION CHAMBER.
C. FUEL INJECTION
AIR SWIRL CONTINUES TO REMOVE ONLY THE UPPER SURFACE OF DEPOSITED FUEL ON THE PISTONS IN SPHERICAL COMBUSTION CHAMBER THROUGHOUT THE POWER STROKE OF PISTON, MAINTAINING EVEN COMBUSTION.
D. POWER STROKE
BURNED GASES THEN ARE EXHAUSTED ON THE EXHAUST STROKE OF PISTON TO COMPLETE THE CYCLE.
E. EXHAUST STROKE

3. Injection Systems

a. *Fuel Injection Principles.*

(1) *Methods.* There are two methods of injecting fuel into a compression-ignition engine. One method is air injection. This method uses a blast of air to force a measured charge of fuel into the combustion chamber. The other method is solid injection, where direct mechanical pressure is placed on the fuel itself to force it into the combustion chamber. Only the solid injection system will be discussed in this task because air injection is virtually unused in automotive applications.

(2) *Fuel Atomization and Penetration.* The fuel spray entering the combustion chamber must conform to the chamber's shape so that the fuel particles will be well distributed and thoroughly mixed with the air. The shape of the spray is determined by the degree of atomization and penetration produced by the orifice through which the fuel enters the chamber. Atomization is the term used to indicate the size of the droplets into which the fuel is broken down. Penetration is the distance from the orifice that the fuel droplets attain at a given phase of the injection period. The dominant factors that control penetration are the length of the nozzle orifice, the diameter of the orifice outlet, the viscosity of the fuel, and the injection pressure of the fuel. Increasing the ratio of the length of the orifice to its diameter will increase penetration and decrease atomization. Decreasing this ratio will have an opposite effect. Because penetration and atomization are opposed mutually and both are important, a compromise is necessary if uniform fuel distribution is to be obtained. The amount of fuel pressure for injection is dependent on the pressure of the air in the combustion chamber, and the amount of turbulence in the combustion space.

(3) *Function of the Injection System.* It is impossible to cover the operation and construction of the many types of modern injection systems in this lesson. However, the operation of the more common systems will be discussed. If the three basic functions of diesel fuel injection are kept in mind while studying the operation of the systems, it will be easier to understand how they work. The three basic functions are:

(a) To meter the fuel accurately.

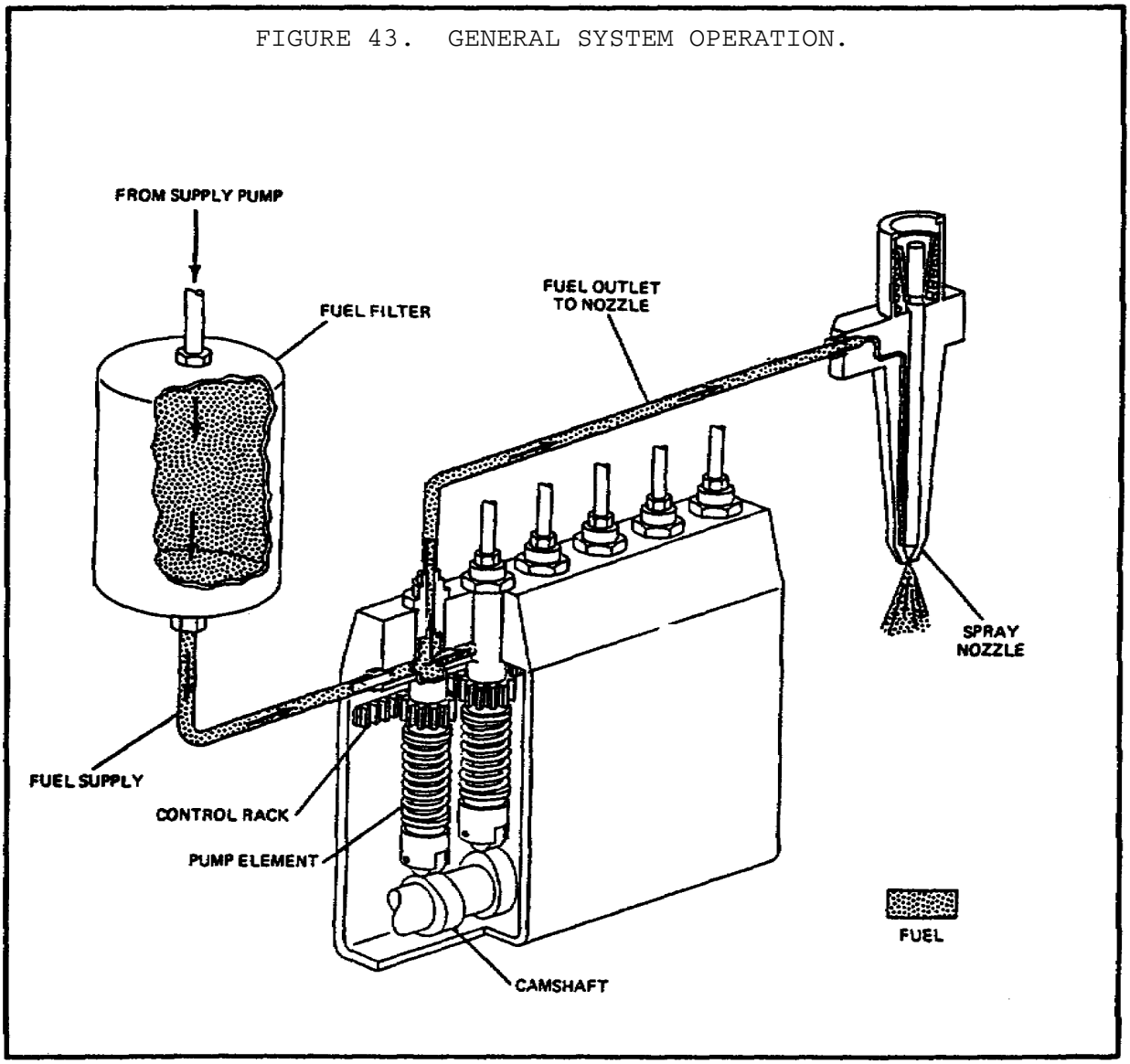
(b) To distribute the fuel equally to all of the cylinders at a high enough pressure to ensure atomization.

(c) To control the start, rate, and duration of the injection.

b. *Multiple Unit Injection.*

(1) *General System Operation* (figure 43). The basic system consists of a fuel supply pump, fuel filter, multiple unit injection pump, and one injector for each cylinder. The operation of the system is as follows:

FIGURE 43. GENERAL SYSTEM OPERATION.



(a) The fuel supply pump and the fuel filter provide a low-pressure supply of fuel to the multiple unit injection pump. Pressure usually is regulated to approximately 15 psi.

(b) The multiple unit injection pump contains an individual injection pump for each engine cylinder. Fuel is delivered from the multiple unit injection pump to the injectors at each cylinder in a timed sequence and a regulated amount, based on accelerator pedal position and engine speed.

(c) The injectors receive fuel charges from their respective injection pumps and spray it into the combustion chambers in a spray pattern that is tailored to provide the best overall performance for their particular application.

(2) *The Multiple Unit Injection Pump.*

(a) The multiple unit injection pump contains an individual plunger-type injector pump for each cylinder. These pumps are arranged in a line so that they may be driven by a common camshaft. The lobes of the camshaft are arranged so that they operate the injection pumps in a sequence that coincides with the firing order of the engine. This camshaft is driven by the engine, through gears, at a speed of exactly one-half that of the crankshaft. This exact speed is maintained so that the injectors will each deliver their fuel charge at the beginning of their respective cylinder's power stroke. Power strokes occur during every other crankshaft revolution in a four-stroke cycle diesel engine.

(b) Excess fuel flows from the injection pump through the relief valve and back to the fuel tank. The relief valve usually is adjusted to open at approximately 15 psi.

(c) The pumps consist of a finely fitted plunger that is actuated by the camshaft against the force of the plunger spring. The bore that the plunger rides in has two passages machined into it. One of these passages is the delivery port, through which the pump is filled. The other passage is the spill port, through which excess fuel is discharged. When the plunger is fully in its return position, fuel flows into the pump cavity through the uncovered delivery port and out of the pump cavity through the uncovered spill port. The

pump cavity always is kept full as the fuel flows through. The plunger moves up in its bore as it is actuated by the camshaft, sealing the ports. The fuel that is trapped in the cavity is forced out of the pump and to its respective injector.

(d) The pump plunger has a rectangular slot cut into it that leads from the top face, down the side, and is finally connecting to a helical shaped cavity called the bypass helix. In operation, the slot will allow fuel to pass .to the bypass helix. As the bypass helix passes over the spill port, it will allow a portion of the fuel charge to bypass back to the fuel tank rather than be injected into the engine cylinder. The outer pump sleeve is made to rotate and has gear teeth around its outer diameter. A horizontal toothed rack meshes with these gear teeth to rotate the sleeve without any plunger rotation. By moving the rack back and forth, the outer pump sleeve is rotated, moving the delivery and spill ports in relation to the bypass helix on the pump plunger. This enables the volume of fuel injected to the cylinders to be varied by changing the effective length of the pump stroke (the length of the pump stroke that occurs before the spill port is uncovered by the bypass helix). The rack extends down the whole row of injection pumps so that they are all operated simultaneously. The end result is that the injection pumps can be moved from full to no-fuel delivery by moving the rack back and forth. Rack movement is controlled by a governor.

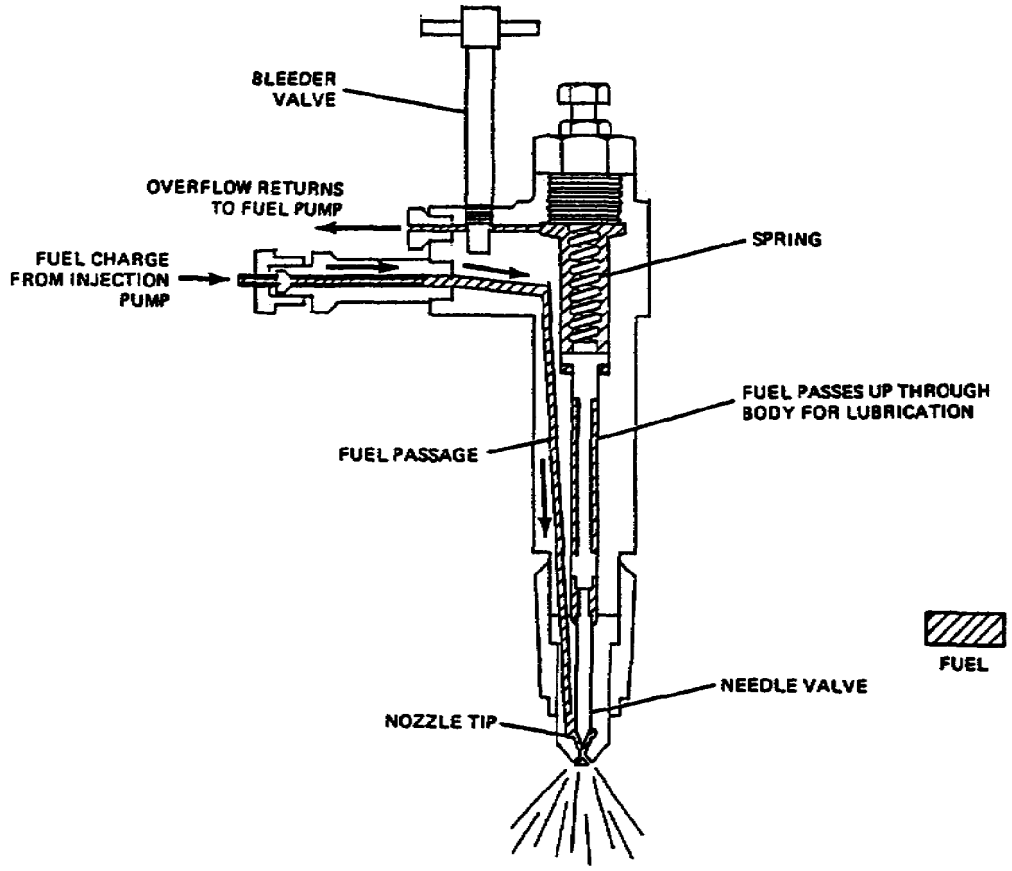
(e) When the plunger begins its pump stroke, it covers both ports. When this happens, the pressure exerted on the fuel causes the spring-loaded delivery valve to lift off of its seat, thereby permitting fuel to discharge into the tubing that leads to the spray nozzle. At the instant the bypass helix uncovers the spill port, the fuel begins to bypass. This causes the pressure in the pump cavity to drop.

High pressure in the delivery line combined with spring pressure causes the delivery valve to close. When the delivery valve closes, it prevents fuel from the line from draining back into the pump, which could cause the system to lose its prime. As the delivery valve seats, it also serves to reduce pressure in the delivery line. The delivery valve has an accurately lapped displacement piston incorporated into it to accomplish pressure relief.

The pressure is relieved in the line by the increase in volume as the delivery valve seats.

(3) *Fuel Injectors* (figure 44). For proper engine performance, the fuel must be injected into the combustion space in a definite spray pattern. This is accomplished by the fuel injector.

FIGURE 44. MULTIPLE UNIT INJECTOR.



(a) The fuel enters the nozzle holder body through the high-pressure inlet. It then passes down to the pressure chamber above the valve seat.

(b) At the moment the pressure developed by the injection pump exceeds the force exerted by the

pressure adjusting spring, the nozzle valve will be lifted off of its seat resulting in the injection of fuel into the cylinder. The valve usually requires a fuel pressure of 1,000 to 40,000 psi to open, depending on the engine combustion chamber requirements.

(c) A controlled seepage exists between the lapped surfaces of the nozzle valve and its body to provide for lubrication. The leakage or overflow passes around the spindle and into the pressure adjusting spring chamber. From here, the fuel leaves the injector through the overflow outlet and finally to the overflow lines, which lead back to the low-pressure fuel supply.

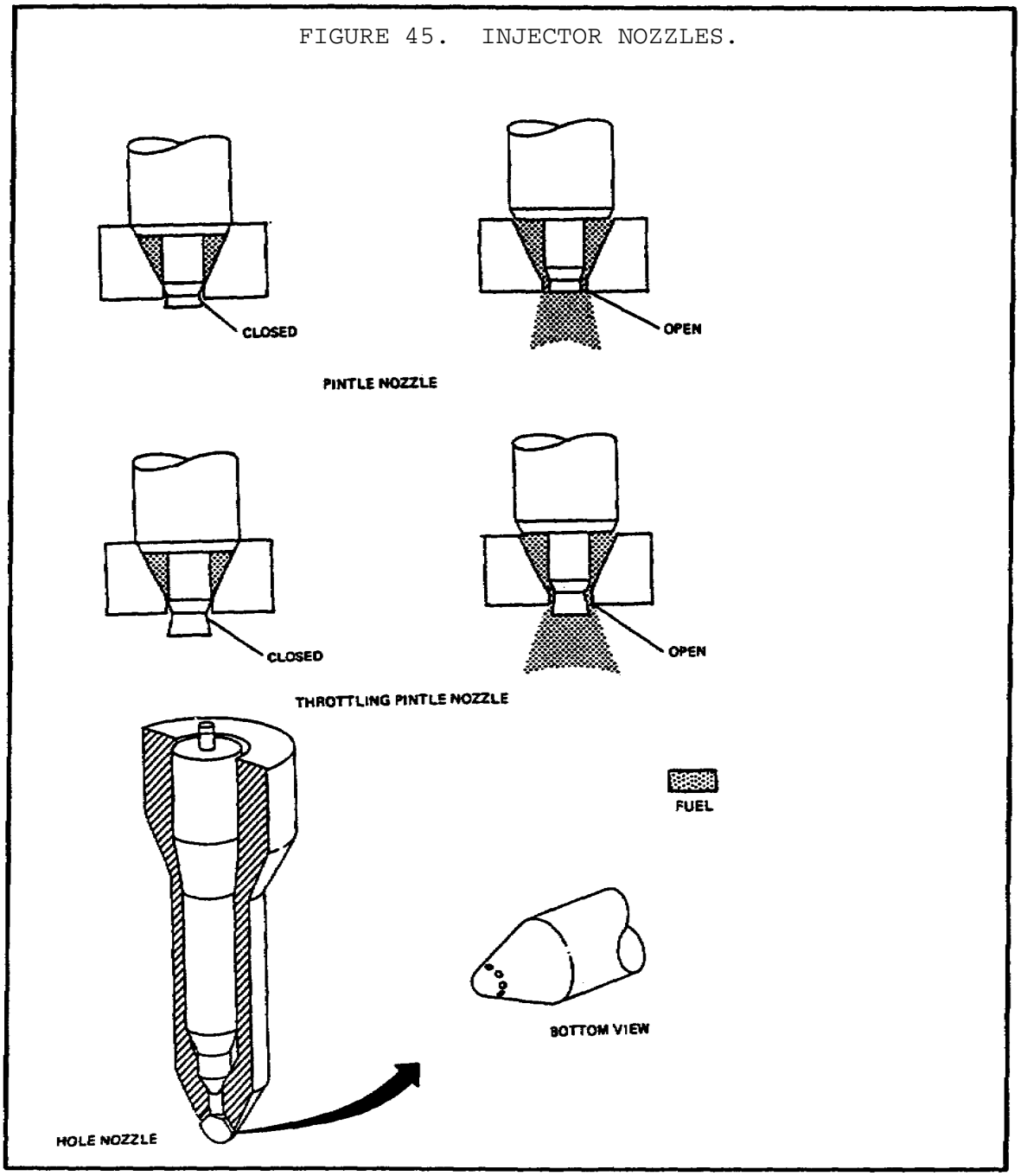
(4) *Injector Nozzles* (figure 45 on the following page). Because of the widely differing requirements in the shapes of the fuel spray for various chamber designs, and the wide range of engine power demands, there is a large variety of injector nozzles in use. The spray nozzles are put into two basic groups: pintle nozzles and hole nozzles. Pintle nozzles generally are used in engines having precombustion or turbulence chambers, whereas the hole nozzles generally are used in open chamber engines.

(a) In pintle nozzles, the nozzle valve carries an extension at its lower end in the form of a pin (pintle) which protrudes through the hole in the nozzle bottom. This requires the injected fuel to pass through an annular orifice, producing a hollow, cone-shaped spray, the nominal included angle of which may be from 0° to 60°, depending on the combustion chamber requirement. The projection of the pintle through the nozzle orifice includes a self-cleaning effect, discouraging the accumulation of carbon at this point.

(b) A specific type of pintle nozzle used extensively in small bore high-speed diesel engines is the throttling nozzle. It differs from the standard pintle nozzle in that the pintle projects from the nozzle for a much greater distance, and the orifice in the bottom of the nozzle body is much longer. The outstanding feature of the throttling nozzle is its control of the rate at which fuel is injected into the combustion chamber. When no fuel is being injected, the pintle extends through the nozzle orifice. At the beginning of the injection period, only a small quantity of fuel

is injected into the chamber because the straight section of the pintle is in the nozzle orifice. The volume of the fuel spray then increases progressively as the pintle is lifted higher, because the straight section leaves the nozzle orifice and the trapped tip of the pintle in the orifice provides a larger opening for the flow of fuel.

FIGURE 45. INJECTOR NOZZLES.



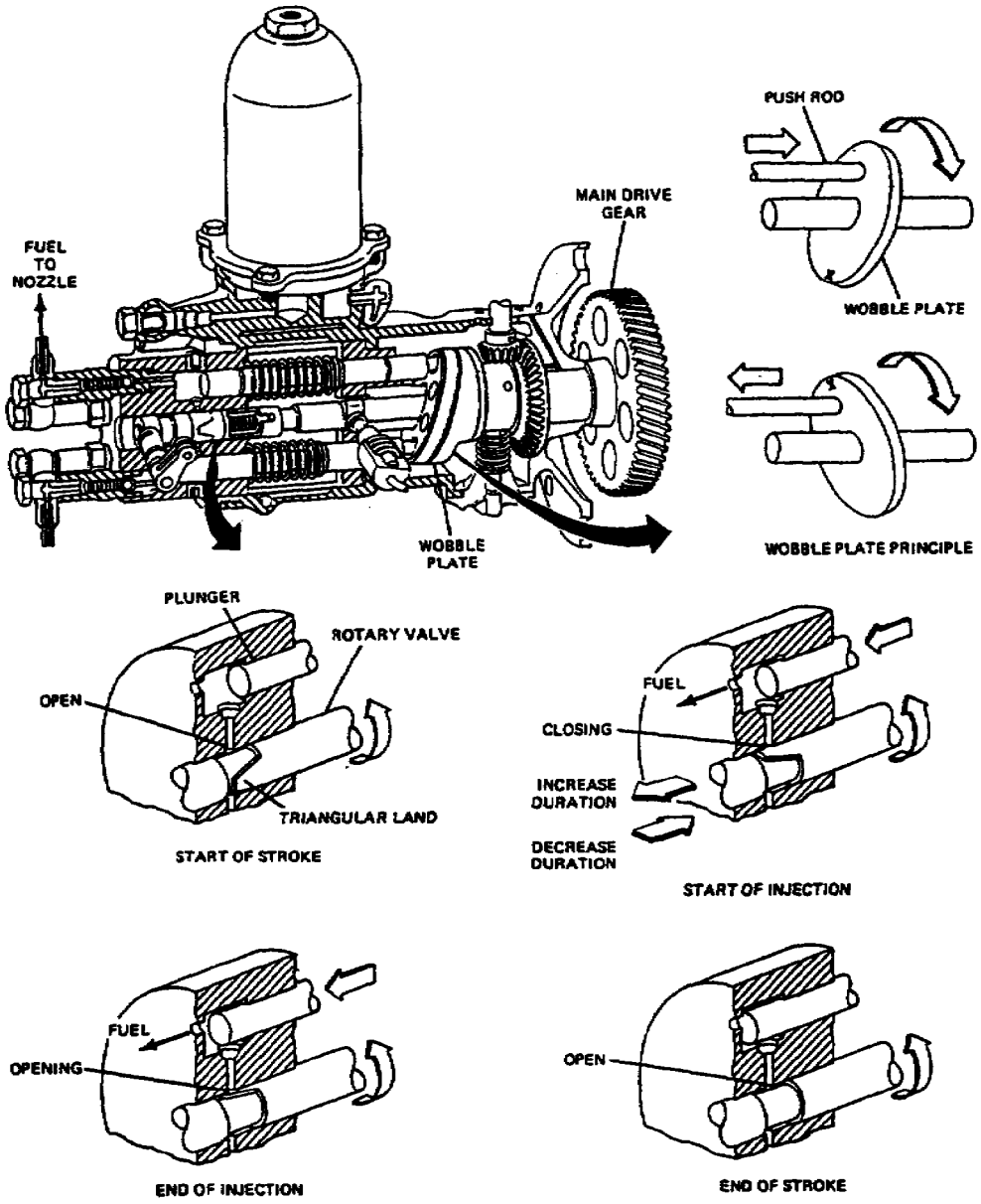
(c) Another type of throttling nozzle has its pintle flush with the nozzle-body tip for no-fuel delivery and extended through the body for maximum fuel delivery. In this type, fuel under high pressure from the injection pump acts on the seat area of the pintle, forcing it outward against a preloaded spring. This spring, through its action on a spring hanger, also returns the pintle to its seat, sealing the nozzle against further injections or dribble when the line pressure is relieved at the pump. When the pintle moves outward due to fuel pressure, an increasingly larger orifice area is opened around the flow angle of the pintle.

(d) The hole nozzles have no pintle but basically are similar in construction to the pintle type. They have one or more spray orifices that are straight, round passages through the tip of the nozzle body beneath the valve seat. The spray from each orifice is relatively dense and compact, and the general spray pattern is determined by the number and the arrangement of the holes. As many as 18 holes are provided in larger nozzles, and the diameter of these drilled orifices may be as small as 0.006 in. The spray pattern may not be symmetrical, as in the case of the multifuel engine, where the spray pattern is off to one side so as to deposit the fuel properly in the spherical combustion chamber. The size of the holes determines the degree of atomization attained. The smaller the holes, the greater the atomization; but if the hole is too small, it will be impossible to get enough fuel into the chamber during the short time allowed for injection. If the hole is too large, there will be an overrich mixture near the nozzle tip and a lean mixture at a distance from it. Using multiple holes in the injector tips usually overcomes both difficulties because the holes can be drilled small enough to provide proper atomization and in a sufficient number to allow the proper amount of fuel to enter during the injection period.

c. *Wobble Plate Pump System* (figure 46 on the following page).

(1) *General System Operation.* The wobble plate pump system basically is the same as the multiple unit injection system. The difference in the systems lies in the injection pump. In a wobble plate pump, all of the pump plungers are actuated by a single wobble plate instead of a camshaft that

FIGURE 46. WOBBLE PLATE INJECTION PUMP.



has a separate cam for each pump plunger. Also, the metering of the fuel is accomplished by a single axially located rotary valve in the wobble plate unit, whereas the rotary movement of the individual plungers controls the amount of fuel in the multiple unit injection pump.

(2) *Wobble Plate Pump Principles.* A plate is mounted on a shaft and set at an angle to it so that as the shaft rotates, the plate moves laterally in relation to any given point on either side of it. The pump derives its name from the fact that the plate appears to wobble back and forth as it rotates. The end of the push rod is placed in a guide plate that lays against the wobble plate. The push rod is held in a bore in the pump body so that it can move only in a direction parallel to the wobble plate shaft. The rotation of the wobble plate then causes the guide plate to wobble, thus moving the push rod back and forth. The push rod is connected to the pump plunger so that movement to the left actuates the pump on its delivery stroke and a spring returns it on the suction stroke.

(3) *The Wobble Plate Injection Pump.* As in the multiple unit injection pump, the wobble plate injection pump contains an individual plunger-type pump for each cylinder. The pump plungers are spaced equally about the wobble plate. As the wobble plate rotates, it will actuate all of the individual injection pumps. At any given time during rotation, half of the plungers will be moving on their delivery stroke while the other half will be on their return stroke.

(a) The rotary metering valve is driven by the same shaft that drives the wobble plate. The rotary valve consists of a lapped cylindrical shaft that is fitted closely in a barrel to prevent fuel from escaping at its ends. Fuel is admitted to the barrel at the center of the valve, which contains a spoonlike reduction in diameter. This reduction in diameter acts as a fuel reservoir.

(b) The reduced portion of the valve is in the shape of a band broken by a triangular land that is the same diameter as the ends of the valve. The reservoir created by the reduced portion of the valve is connected to each pump cavity by individual ports so that the pump cavities may be supplied with fuel. This reservoir receives a

constant supply of low-pressure fuel from the delivery pump. As with the multiple unit injection system, delivery pump pressure is regulated to approximately 15 psi.

(c) The triangular land serves to consecutively block each pump delivery port as it rotates. The triangular land is situated so that it will block each pump delivery port at the same time that the wobble plate is moving the respective pump plunger at the maximum speed through its delivery stroke.

(d) The rotational relationship of the rotary valve and the wobble plate causes each pump to deliver a fuel charge to its respective injector in turn as the pump rotates. The pumps in the injection unit are connected to the fuel injectors to coincide with the firing order of the engine. The pump is gear driven by the engine at a speed of exactly one-half that of the crankshaft. The end result will be the injection of fuel to each cylinder at the beginning of each power stroke.

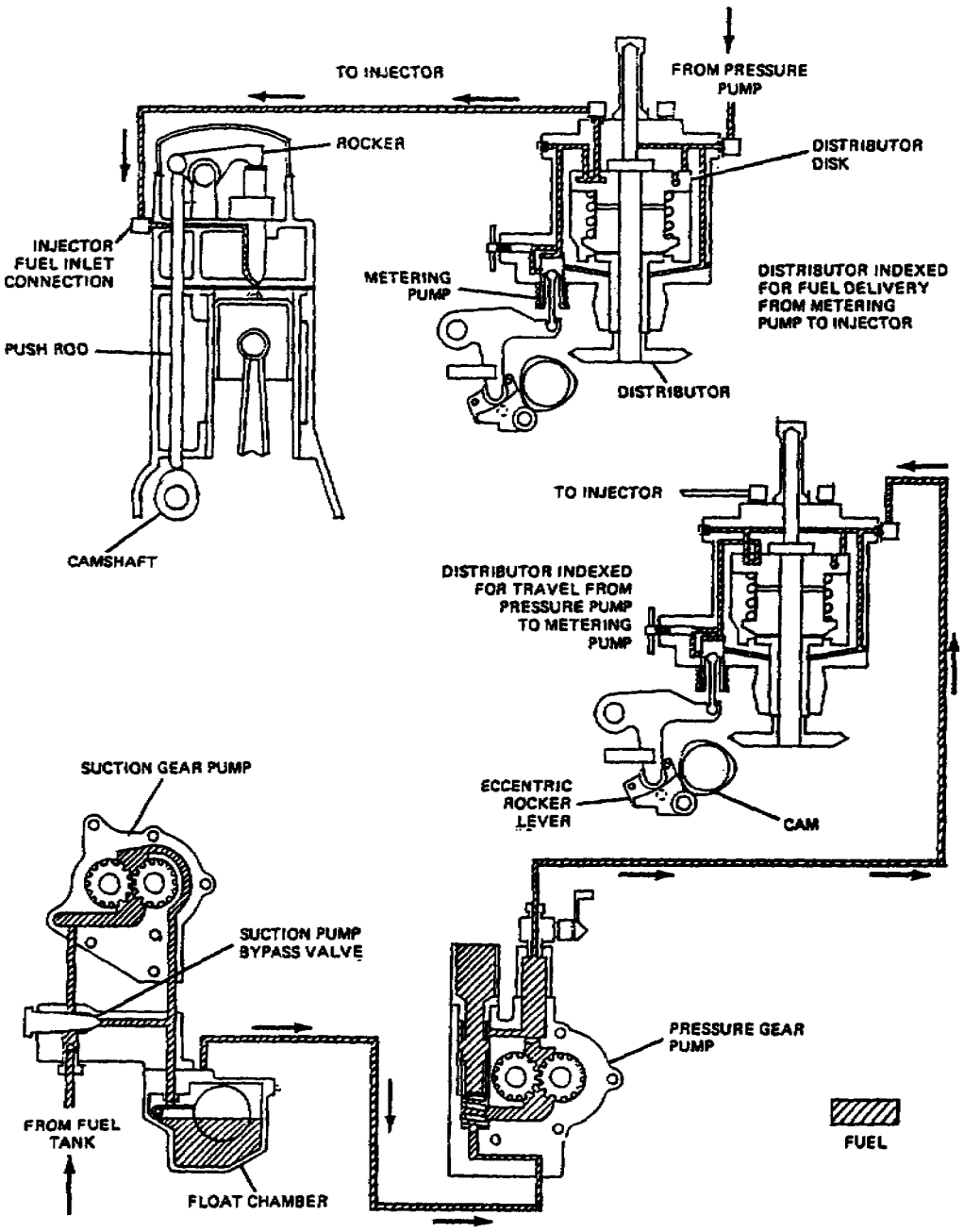
(e) To obtain zero delivery, the valve is moved endwise to a position where the delivery ports are never blocked by the triangular land. When this occurs, the movement of the pump plungers merely causes the fuel to move back and forth in the delivery ports. This results in zero delivery to the injectors due to insufficient pressure to open the spring-loaded delivery valves.

(f) To cause the pump to deliver fuel, the rotary valve is moved endwise so that the triangular land begins to block the delivery ports. Due to the triangular shape of the land, further endwise movement of the rotary valve will increase the time that the port is blocked, increasing fuel delivery. The end result is that fuel delivery can be controlled by the endwise movement of the rotary valve. Endwise movement of the rotary valve is accomplished by the control lever. The position of the control lever is determined by the governor.

d. *Distributor-Type Injection System.*

(1) *General System Operation* (figure 47 on the following page). The distributor injection system used in automotive diesel engines is classed as a low-pressure system in that pumping, metering, and distribution operations take place at low pressure. The high pressure required for injection

FIGURE 47. DISTRIBUTOR INJECTION SYSTEM.

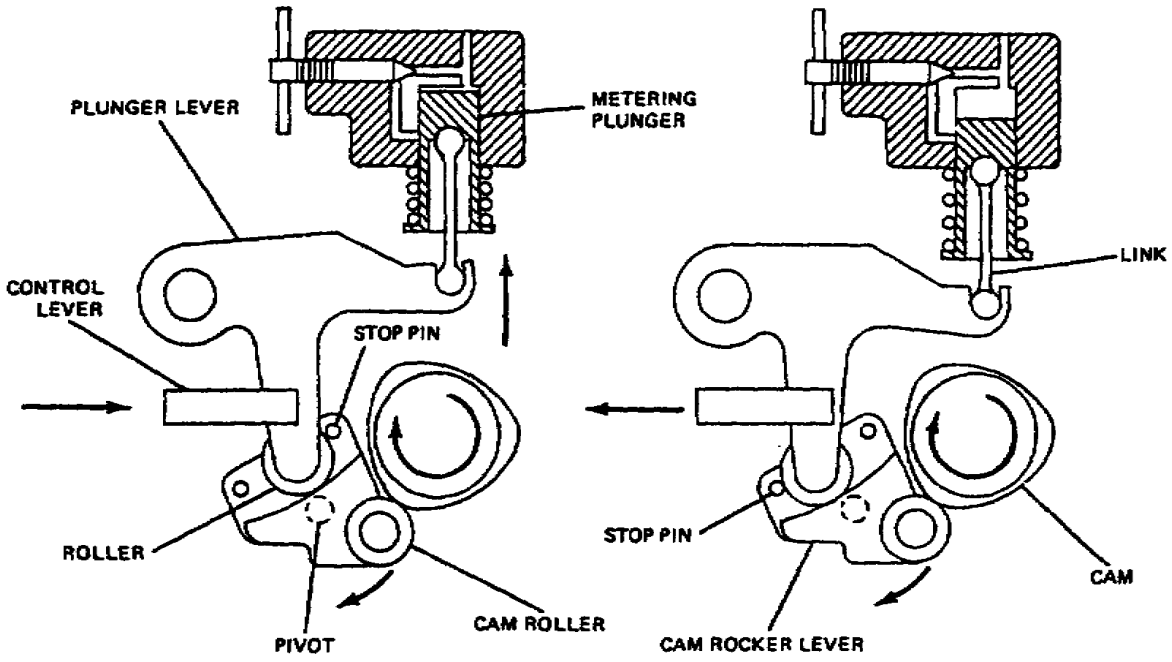


is built up by the injector at each cylinder. A suction pump lifts fuel from the tank and delivers it to the float chamber. From here a second low-pressure pump delivers the fuel to the distributor. Fuel passes through the distributor to the metering pump, where it is divided into measured charges. The fuel charges are then delivered back to the distributor, where they are sent to the injectors in the proper sequence. The measured charges and then sprayed into the engine cylinders, at the proper time and under high pressure, by the fuel injectors.

(2) *Distributor.* The distributor consists of a rotating disk and a stationary cover to which the fuel lines to the individual injectors are connected. The disk and the cover have a series of holes which, when properly indexed, form passages from the fuel supply pump to the metering pump. The disk is timed so that this occurs when the metering plunger is moving down on its suction stroke, thus permitting the metering pump to be filled with oil. As the disk continues to rotate, it lines up with the correct discharge hole in the cover just as the metering plunger begins its delivery stroke, forcing the fuel into the proper injector line. As it continues to rotate, the disk works in the same timed sequence in conjunction with the metering pump to feed fuel to the remaining cylinders. The rotating disk turns at one-half crankshaft speed because power strokes occur every other crankshaft revolution in a four-stroke cycle diesel engine.

(3) *Metering Unit* (figure 48 on the following page). The metering unit is a closely fitted reciprocating pump, obtaining its motion through a link from the plunger lever. The plunger lever is operated by a vertical lever, controlled in turn by an eccentric rocker lever running directly off a cam on the fuel pump main shaft. The position of the vertical lever in the eccentric of the rocker lever determines the travel of the plunger lever and, in turn, the travel of the metering pump plunger. As the pump plunger starts upward on its controlled stroke, it pushes fuel to the injector through passages formed by the rotating distributor disk. The stroke of the metering plunger, which determines the amount of fuel going to each injector, is varied by changing the position of the plunger lever between the stop pins in the cam rocker lever. The position of the plunger lever is adjusted by the governor through the control lever.

FIGURE 48. FUEL METERING SYSTEM.

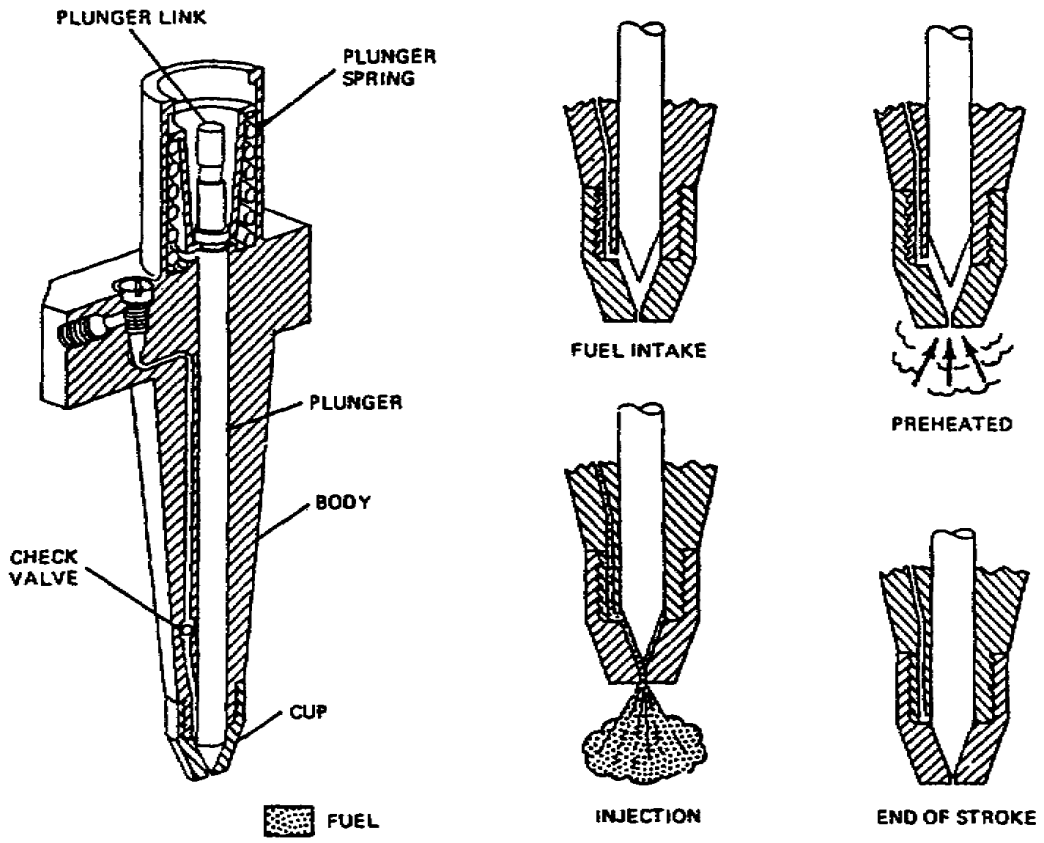


(4) *Injectors* (figure 49 on the following page). The injector consists of a forged body with a properly fitted plunger. This plunger is forced down by the engine camshaft against spring action through a rocker arm and push rod. A fuel cup is mounted on the end of the body, combined with a hole-type nozzle.

(a) The fuel metering pump forces a precisely measured fuel charge into the cup on the intake stroke of the engine. The quantity of the fuel charge is based on the speed and load requirements of the engine. The operation of this system depends on the injector delivery line being full of fuel. It will then follow naturally that any fuel added by the fuel metering pump will expel an equal amount of fuel into the injector.

(b) The fuel lies in the cup during the compression stroke of the engine, and the compressed air is forced through the small spray holes in the cup. The fuel in the tip of the cup is exposed to the intense heat of compression. The air rushing in through the holes in the nozzle tip serves to break the fuel charge into droplets.

FIGURE 49. DISTRIBUTOR-TYPE UNIT INJECTORS.



(c) A few degrees before top dead center, at the beginning of the power stroke, the injector plunger is forced down, causing the fuel charge to be sprayed out of the cup through the nozzle holes and into the combustion chamber. The downward movement of the injector plunger is spread out through the entire power stroke.

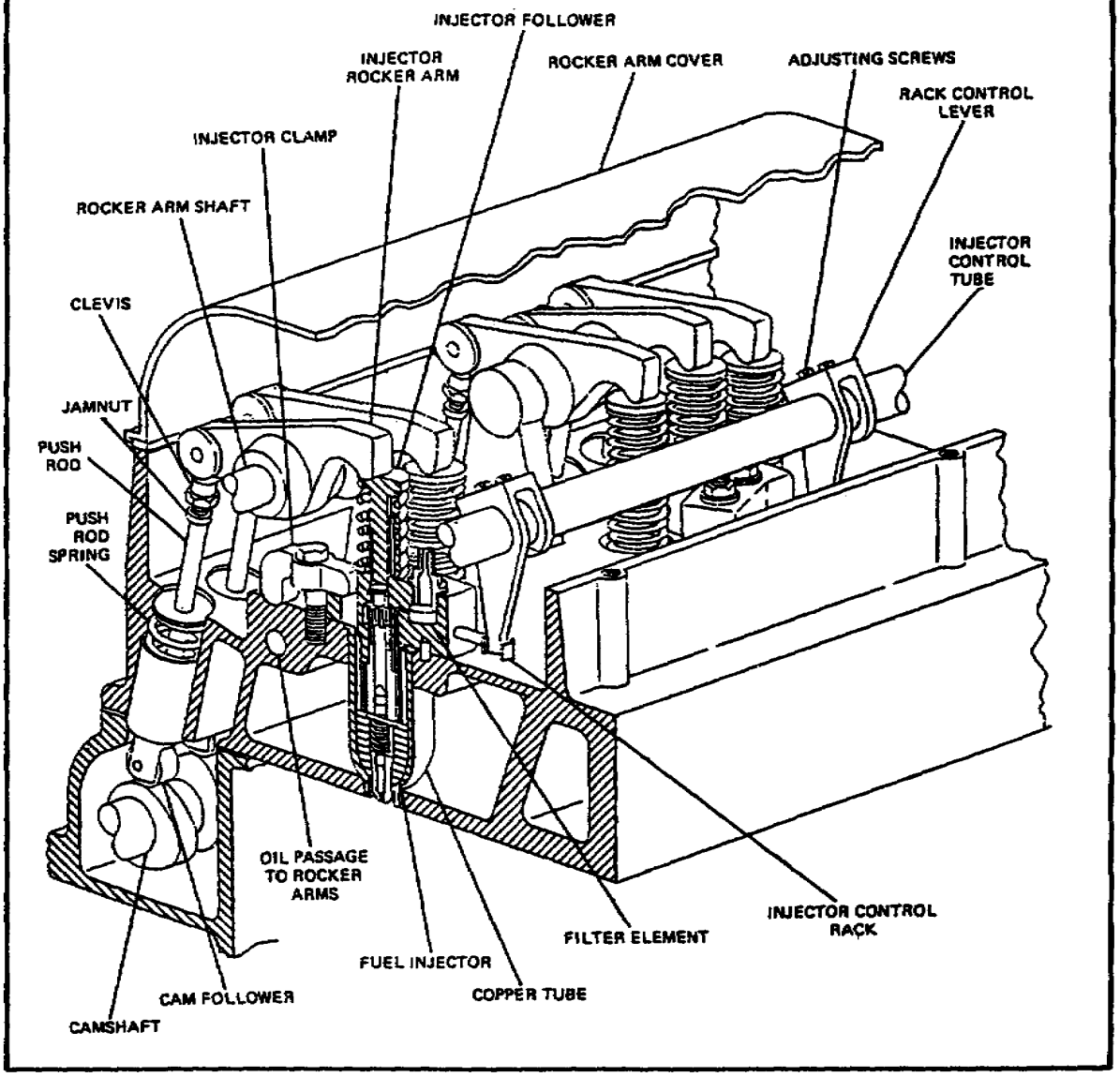
(d) There is a small check valve located in the inlet passage of the injector body. Its purpose is to allow fuel to enter the injector cup but block high combustion chamber pressure from blowing air into the injector delivery lines.

e. *Unit Injection System* (figure 50 on the following page).

(1) *Overall System Operation.* The unit injection system operates in the same manner as the multiple unit injection system. The difference is that rather than using a centrally located unit to

house the high-pressure pumps, control racks, pressure regulators, and delivery valves, they are all incorporated into each injector. This eliminates the need for high-pressure lines or any other apparatus besides the fuel supply pump.

FIGURE 50. UNIT INJECTION SYSTEM.

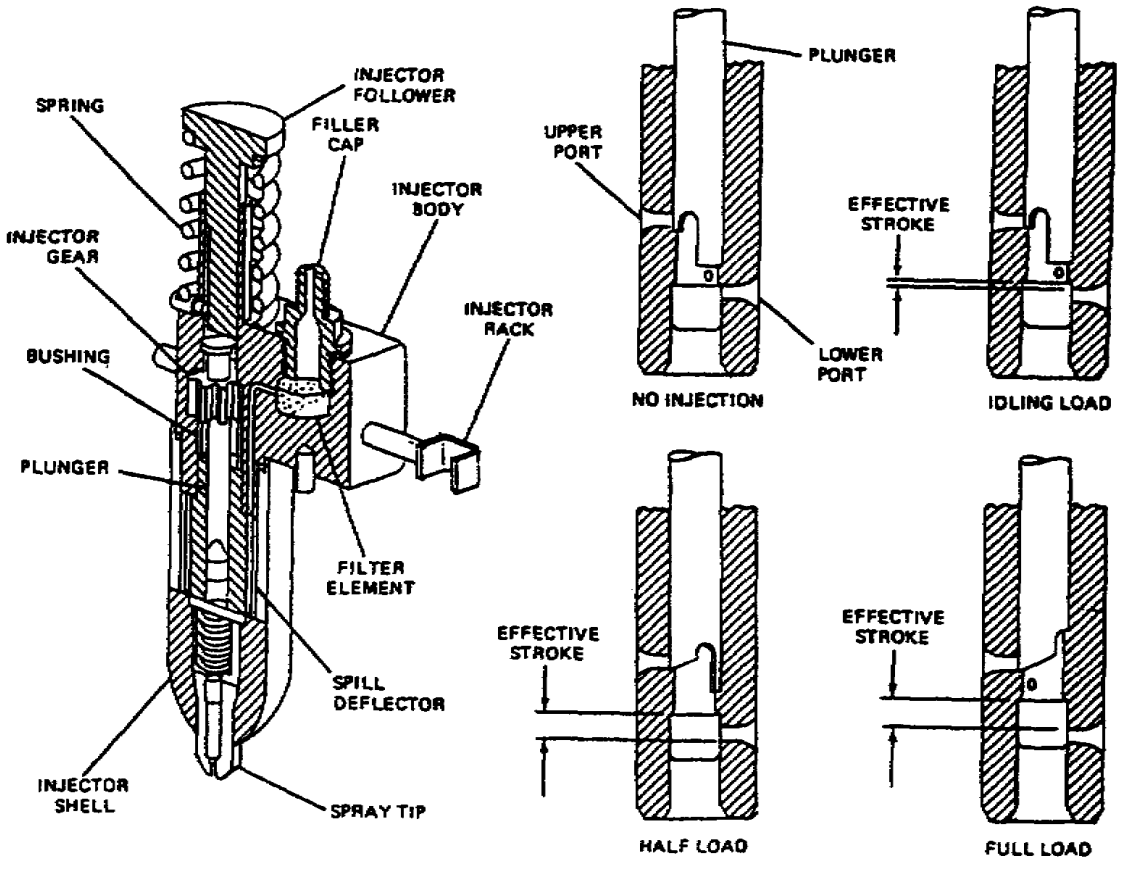


(2) *Fuel Supply.* Fuel is drawn from the fuel tank by the fuel supply pump, through the primary fuel filter, and directly to the individual injector units. The fuel is supplied at low pressure, approximately 20 psi.

(3) *Injector Units* (figure 51). Unit injectors combine the injection pump, the fuel valves, and the nozzle in a single housing. These units provide a complete and independent injection system for each cylinder. The units are mounted in the cylinder head with their spray nozzles protruding into the combustion chamber. A clamp, bolted to the cylinder head and fitting into a machined recess in each side of the injector, holds the injector in place in a water-cooled copper tube that passes through the cylinder head. The tapered lower end of the injector seats in the copper tube, forming a tight seal to withstand the high pressures inside the cylinder. The injector operates as follows:

(a) Fuel is supplied to the injector through the filter cap. After passing through a finegrained filter element in the inlet passage, the fuel fills the annular shaped supply chamber that is created between the bushing and the spill deflector.

FIGURE 51. UNIT INJECTOR OPERATION.



(b) The bushing bore is connected to the fuel supply by two funnel shaped ports, one on each side at different heights. The plunger operates up and down in the bushing bore.

(c) The plunger is actuated by a camshaft that is built right into the engine. The operation takes place through a rocker arm and push rod. The push rod has a roller-type cam follower and is spring loaded to prevent component damage in the event of injector nozzle clogging. The plunger is situated under a follower. This follower is spring-loaded to make it follow the camshaft.

(d) The plunger can be rotated in operation around its axis by the gear, which is meshed to the control rack. Each injector rack is connected by an easily detachable joint to a lever on a common control tube which, in turn, is linked to the governor and the throttle.

(e) For metering purposes, a recess with an upper helix and a lower helix, or a straight cutoff, is machined into the lower end of the plunger. The relation of this upper helix and lower cutoff to the two ports changes with the rotation of the plunger. As the plunger moves downward, the fuel in the high-pressure cylinder or bushing is first displaced through the ports back into the supply chamber until the lower edge of the plunger closes the lower port. The remaining oil is then forced upward through the center passage in the plunger into the recess between the upper helix and the lower cutoff, from which it can flow back into the supply chamber until the helix closes the upper port. The rotation of the plunger, by movement of the rack, changes the position of the helix in relation to the ports. This will advance or retard the closing of the ports and the beginning and ending of the injection period. This will result in a regulation of the volume of the fuel charge that is injected into the cylinder.

(f) When the control rack is pulled out completely, the upper port is not closed by the helix until after the lower port is uncovered. This means that all the fuel in the high-pressure cylinder bypasses back to the fuel supply and no fuel is injected into the combustion chamber.

(g) When the control rack is pushed in fully, the upper port is closed shortly after the lower port has been covered, thus producing a full effective stroke and maximum injection.

(h) From the no-delivery to the full-delivery positions of the control rack, the contour of the helix advances the closing of the ports and the beginning of injection.

(i) On the downward travel of the plunger, the metered amount of fuel is forced through the center passage of the valve assembly, through the check valve, and against the spray tip valve. When sufficient fuel pressure is built up, the spray tip valve is forced off its seat and fuel is discharged through the hole-type injector nozzle. The check valve prevents air leakage from the combustion chamber into the fuel system should the spray tip valve not seat properly.

(j) On the return upward movement of the plunger, the high-pressure cylinder is again filled with oil through the ports. The constant circulation of fuel through the injectors back through the return helps to maintain an even operating temperature in the injector, which would otherwise tend to run very hot due to extreme pressures. Constant circulation also helps to remove all traces of air from the system. The amount of fuel circulated through the injector is in excess of maximum needs, thus ensuring sufficient fuel for all conditions.

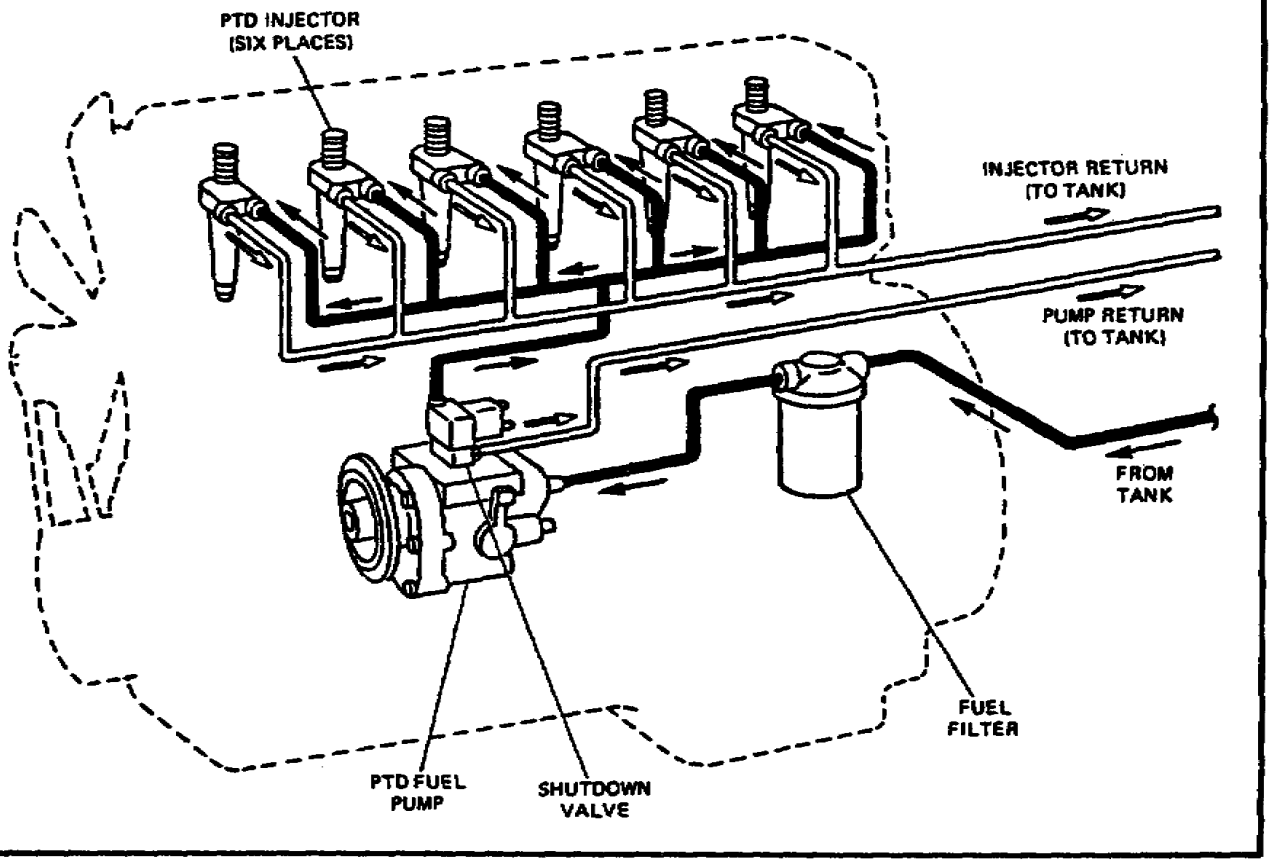
f. *Pressure-Timed (PT) Injection System*

(1) *Overall System Operation* (figure 52 on the following page). The pressure-timed injection system has a metering system based on the principle that the volume of liquid flow is proportional to the fluid pressure, the time allowed to flow, and the size of the passage the liquid flows through. The operation of the system is as follows:

(a) A fuel tank with a vented filler cap stores the fuel supply.

(b) Fuel is supplied from the tank to the pressure-timed gear (PTG) pump through the delivery line. An in-line filter is placed in series in the line to trap foreign matter and moisture.

FIGURE 52. PRESSURE-TIMED INJECTION SYSTEM.



(c) A return line from the PTG pump to the fuel tank is provided to bleed off excess fuel so that operating pressures can be regulated.

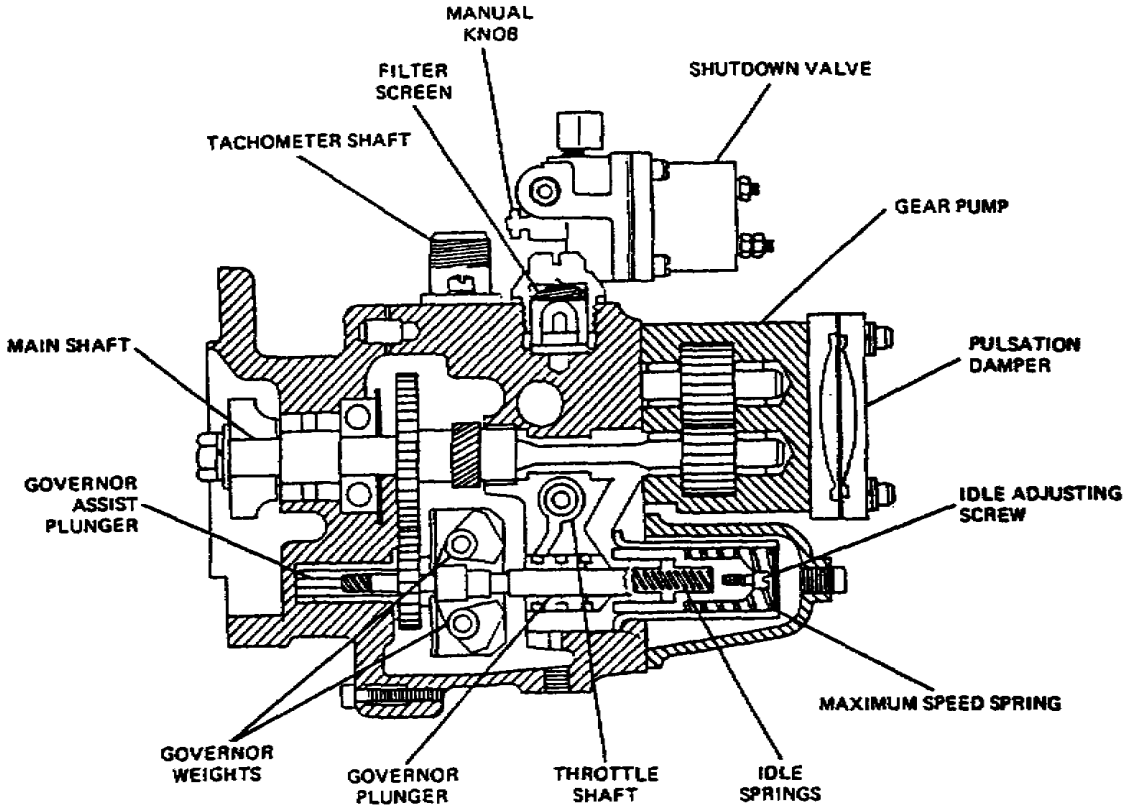
(d) The PTG pump delivers controlled amounts of fuel to pressure-timed delivery (PTD) injectors.

(e) Delivery of fuel to the PTD injectors is through a common-rail type delivery line.

(f) A common-rail type return line connects the PTD injectors to the fuel tank so that excess fuel may be diverted back to the fuel tank.

(2) PTV Injection Pump (figure 53 on the following page). The PTG pump is driven directly by the engine at a one-to-one speed ratio. The pump contains four main components. These four components and their operations are described as follows:

FIGURE 53. PRESSURE-TIMED GEAR PUMP.



(a) The gear-type pump draws fuel from the supply tanks and forces it through the pump filter screen to the governor. It is driven by the pump main shaft and picks up and delivers fuel throughout the fuel system. A pulsation damper mounted to the gear pump contains a steel diaphragm that absorbs pulsations and smooths fuel flow through the fuel system. From the gear pump, fuel flows through the filter screen to the governor screen. The PTG pumps are equipped with a bleed line that is attached to the engine injector return line or to the tank. This prevents excessive fuel temperature within the fuel pump by using the surplus fuel as a coolant. The bleed line functions primarily when the pump throttle is set at idle speed, but gear pump output is high due to engine operating speed, as occurs during downhill operation. A special check valve and/or fitting is used in the gear pump to accomplish the bleed action.

(b) The governor controls the flow of the fuel from the gear pump, as well as the maximum and idle speeds. The mechanical governor is actuated by a system of springs and weights and has two functions: First, the governor maintains sufficient fuel for idling with the throttle control in idle position; second, it will restrict fuel to the injectors above maximum rated rpm. The idle springs (in the governor spring pack) position the governor plunger so the idle fuel port is opened enough to permit passage of fuel to maintain engine idle speed.

During operation between idle and maximum speeds, fuel flows through the governor to the injector in accordance with the engine requirements, as controlled by the throttle and limited by the size of the idle spring plunger counterbore on the PTG fuel pumps. When the engine reaches governed speed, the governor weights move the governor plunger, and fuel flow to the injectors is restricted. At the same time, another passage opens and dumps the fuel back into the main pump body. In this manner, engine speed is controlled and limited by the governor, regardless of throttle position. Fuel leaving the pump flows through the shutdown valve, inlet supply lines, and into the injectors.

(c) The throttle provides a means for the operator to manually control engine speed above idle, as required by varying operating conditions of speed and load. In the PTG pump, fuel flows through the governor to the throttle shaft. At idle speed, fuel flows through the idle port in the governor barrel, past the throttle shaft. To operate above idle speed, fuel flows through the main governor barrel port to the throttling hole in the shaft.

(d) The fuel shutdown valve is located on top of the fuel pump. It shuts off fuel to the injectors. With the master switch on, the solenoid opens the valve. With the switch off, the spring loaded valve returns to the OFF position. In case of an electrical failure, rotation of the manual knob clockwise will permit fuel to flow through the valve. The knob is located on the front valve.

(3) *PTD Injectors.* A PTD injector is provided at each engine cylinder to spray the fuel into the combustion chambers. PTD injectors are of the unit

type, operated by an engine-based camshaft. Fuel flows from a connection at the top of the fuel pump shutdown valve, through a supply line, into the lower drilled passage in the cylinder head at the front of the engine. A second drilling in the head is aligned with the upper injector radial groove to drain away excess fuel. A fuel drain at the flywheel end of the engine allows return of the unused fuel to the fuel tank. There are four phases of injection operation:

(a) *Metering* (figure 54, view A, on the following page). This phase begins with the plunger just beginning to move downward when the engine is on the beginning of the compression stroke. The fuel is trapped in the cup, the check ball stops the fuel from flowing backwards, and the fuel begins to be pressurized. The excess fuel flows around the lower annular ring, up the barrel, and is trapped there.

(b) *Preinjection* (figure 54, view B, on the following page). The plunger is almost all the way down, the engine is almost at the end of the compression stroke, and the fuel is being pressurized by the plunger.

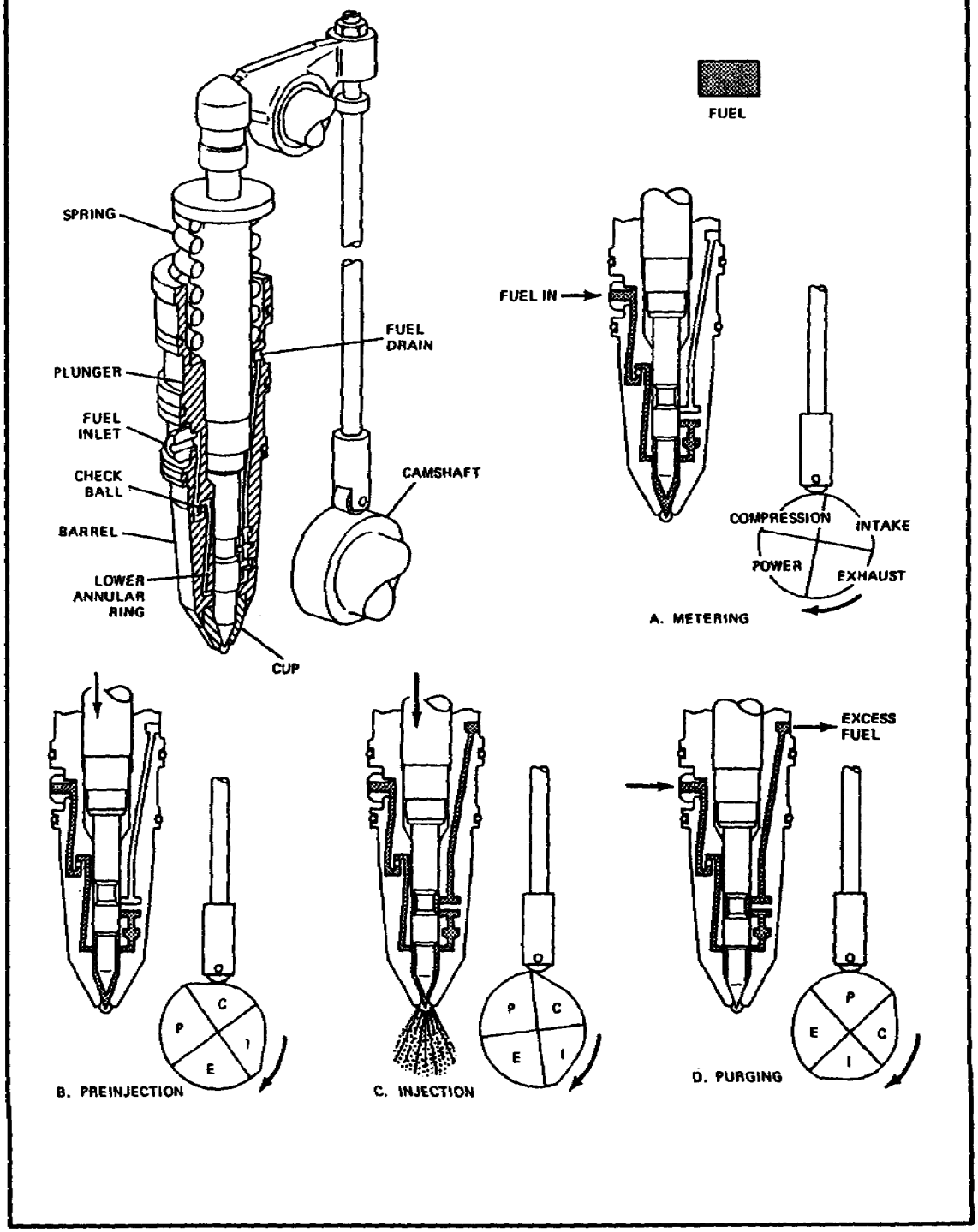
(c) *Injection* (figure 54, view C, on the following page). The plunger is almost all the way down, the fuel is injected out the eight orifices, and the engine is on the very end of the compression stroke.

(d) *Purging* (figure 54, view D, on the following page). The plunger is all the way down, injection is finished, and the fuel is flowing into the injector, around the lower annular groove, up a drilled passageway in the barrel, around the upper annular groove, and out through the fuel drain. The cylinder is on the power stroke. During the exhaust stroke, the plunger moves up and waits to begin the cycle all over again.

g. *PBS Distributor Injection System.*

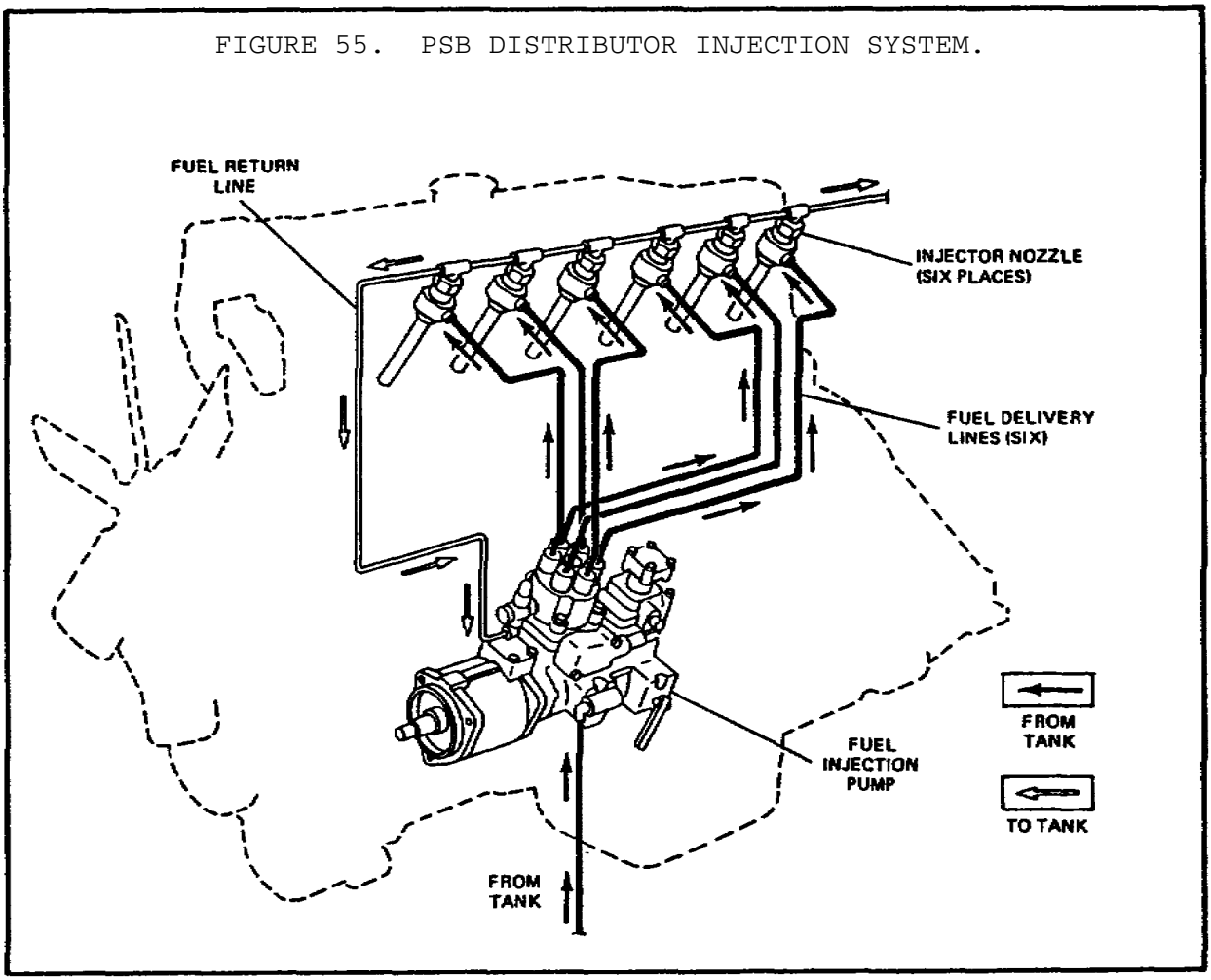
(1) *Overall System Operation* (figure 55 on page 93). The PSB distributor system uses a pump that sends measured charges of fuel to each injector at a properly timed interval. The difference in the PSB system is that the charges of fuel are sent directly from the pump at the high pressure that is necessary for injection. This

FIGURE 54. PRESSURE-TIMED DELIVERY INJECTION SYSTEM



eliminates the need for unit-type injectors and the associated linkage and camshafts, making the system less cumbersome. The injectors are of the same basic design as the ones used in the multiple unit injection system. The nozzles usually are of the hole-type.

FIGURE 55. PSB DISTRIBUTOR INJECTION SYSTEM.

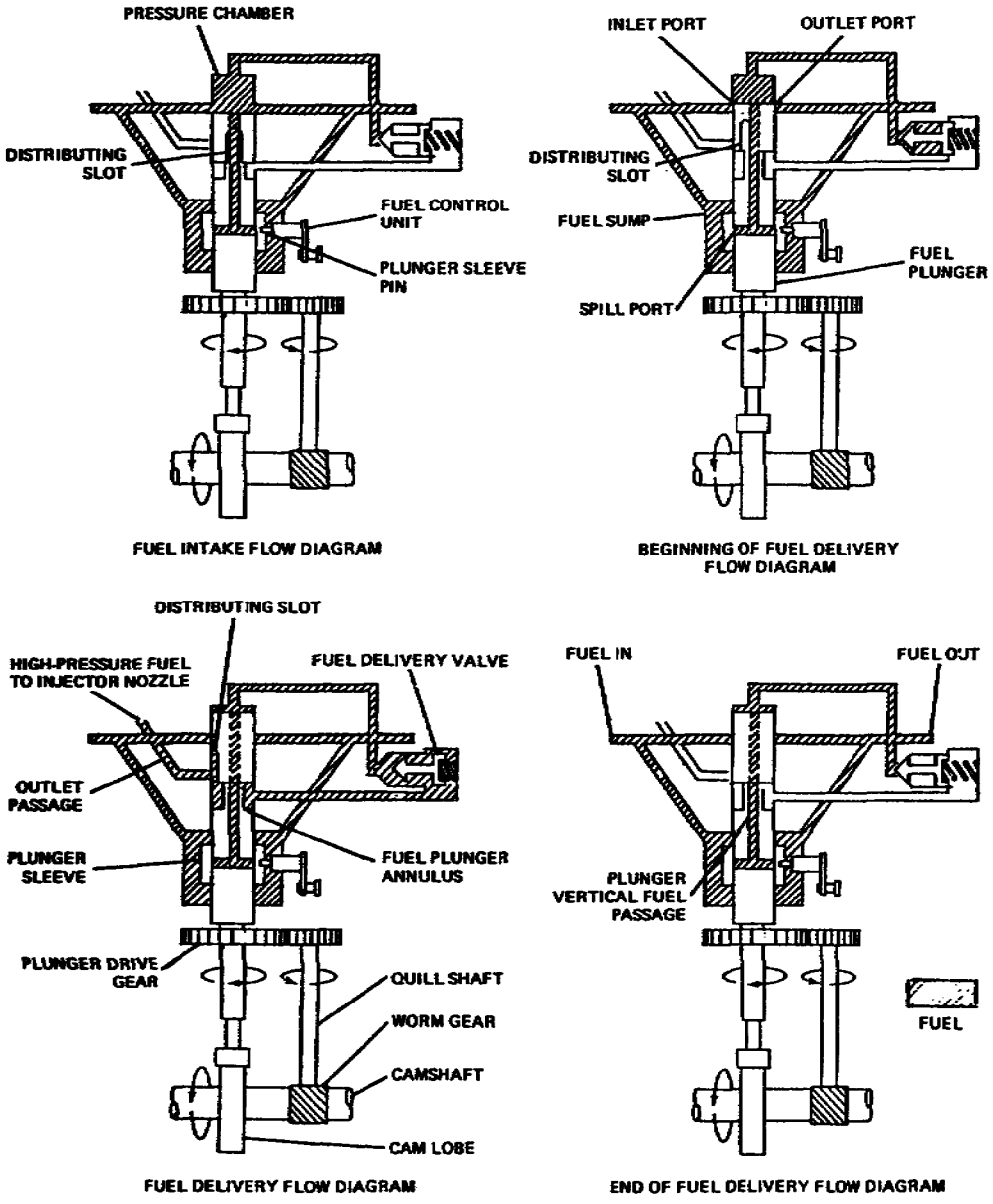


(2) *The PSB Injector Pump.* The PSB injection pump is compact and self-contained, housing all components of the injectors. Operation is shown in figure 56 on the following page.

(a) The PSB pump contains a plunger-type pump that creates the high-pressure fuel charges for the injectors. The pump is driven by a camshaft that is contained within the PBS unit. Fuel is delivered to the PBS pump from the fuel tank by the fuel delivery pump at a regulated pressure of approximately 20 psi. The low pressure fuel supply enters the pump chamber through the inlet port when the plunger is retracted fully. As the plunger

begins its delivery stroke, the fuel inlet passage is blocked, trapping fuel in the pump chamber. The delivery stroke of the plunger then pushes the charge of fuel out of the chamber through the delivery passage. The high-pressure fuel charge then unseats the delivery valve, allowing it to flow into the distribution chamber.

FIGURE 56. PSB INJECTION PUMP OPERATION.



(b) The pump plunger has a spoonlike recess in its diameter about halfway down its sides which, in conjunction with the pump cylinder, forms the distribution chamber. A slot is cut into the plunger at the top of the distribution chamber. As it reciprocates, the plunger is also rotated through a quill gear. As it rotates, the slot lines up with equally spaced passages around the inside of the plunger bore. Each passage is connected to a fuel injector. The reciprocating and rotating motion are timed so that the plunger will go through a delivery stroke as the slot lines up with each injector passage. This enables the PSB injector pump to deliver a fuel charge to each consecutive injector every time the plunger makes one complete revolution.

(c) The PSB pump is geared to the engine so that the camshaft rotates at crankshaft speed. The cam contains half as many lobes as the engine has cylinders (there would be three cam lobes if the engine had six cylinders). The pump plunger is geared to rotate at one-half of camshaft speed. This arrangement allows the PSB pump to deliver a charge of fuel to each injector for every two crankshaft revolutions corresponding to the requirements of a four-stroke cycle diesel.

(d) A hole, called a spill port, is drilled through the lower portion of the pump plunger. The spill port is connected to the pump chamber by another drilled passage. The spill port is covered by a plunger sleeve whose position is adjusted by the control lever through an eccentrically mounted pin.

(e) The movement of the control lever controls the up and down position of the plunger sleeve. The position of the control lever is determined by the governor. When the sleeve is in its extreme downward position, the spill port is immediately uncovered as the plunger begins its delivery stroke. This causes all of the pressure from the pump chamber to bleed off to the pump return. In this position, there will be no fuel delivery to the injectors.

(f) When the plunger sleeve is in the extreme upward position, the spill port is covered until the plunger almost reaches the end of the delivery stroke. This position will deliver maximum fuel to the injectors. As the plunger moves upward, the

pressure developed in the pump chamber unseats the delivery valve. Fuel flows into the distribution chamber and is sent by the slot in the plunger to whatever injector is scheduled to receive it.

(g) The amount of fuel delivered by each injection charge will increase proportionately as the plunger sleeve is moved from its extreme downward to its extreme upward position. The higher the plunger sleeve, the longer the effective pump stroke (plunger movement before the spill port is uncovered).

4. Fuel Supply Pumps

a. *General.* Fuel injection pumps must be supplied with fuel under pressure for the following reasons:

(1) The injection pumps lack the suction ability to draw fuel from the tank by themselves.

(2) It is important to supply fuel in excess to the injection pump so that fuel may be used to cool and lubricate the system before bypassing it back to the tank.

(3) Without a supply pump, the system would lose its prime whenever the pump is in no-delivery mode.

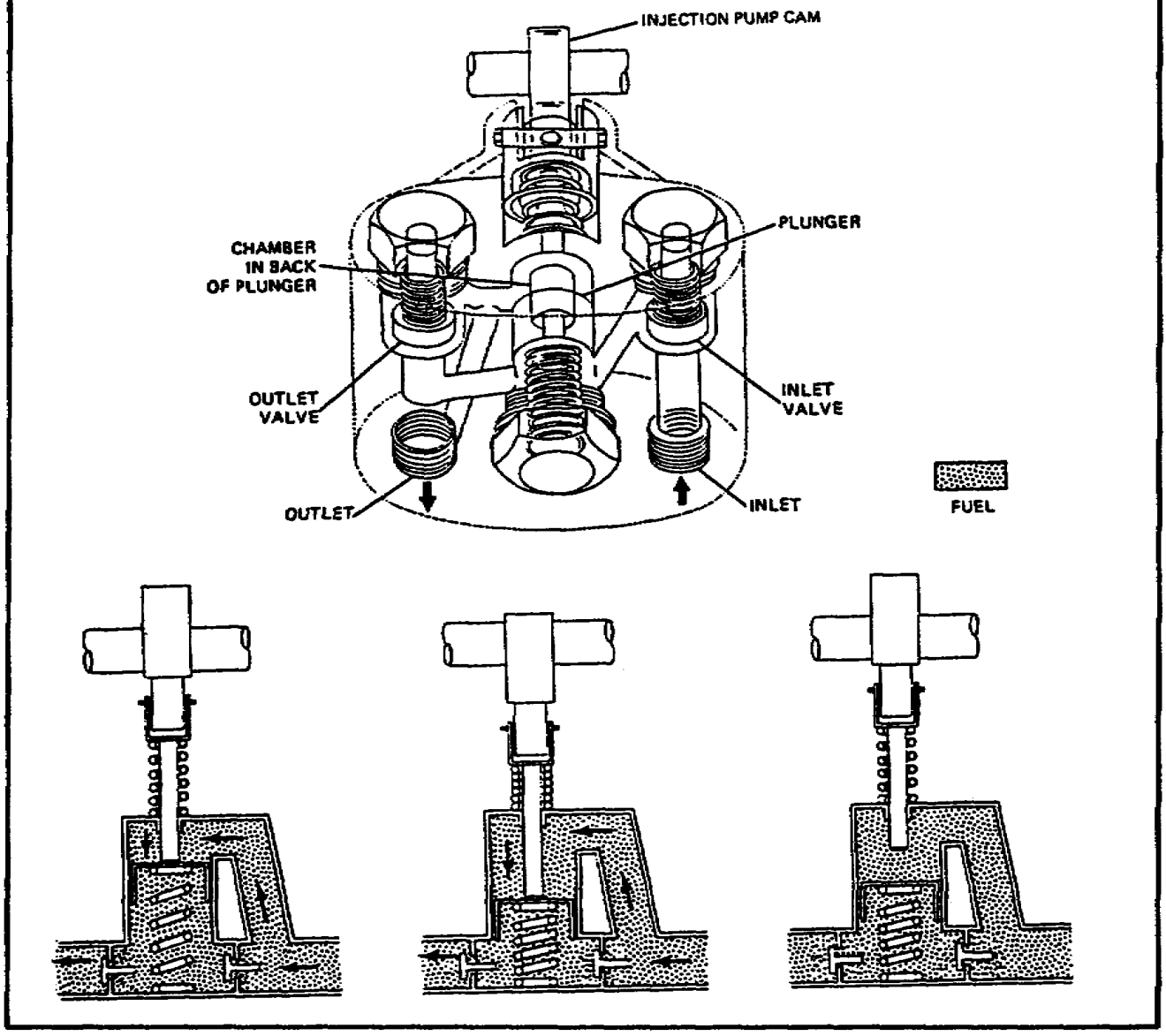
The supply pumps in use generally are of the positive displacement type with a performance that is independent of any reasonable variations in viscosity, pressure, or temperature of the fuel. In a majority of the equipment, the fuel supply pump is built into the injection pump unit. This cuts down on fuel tubing and the complexity of the equipment, and allows the supply pump to share the same engine power takeoff as the injection pump.

b. *Vane-Type Supply Pump.* The basic overall operation of the vane-type supply pump is the same as the vane-type oil pump.

c. *Plunger-Type Supply Pump* (figure 57 on the following page).

(1) This type of pump is always mounted on the injection pump, where it is driven by the injection pump camshaft. It is a variable-stroke, self-regulating pump that will build pressure only up to a predetermined point.

FIGURE 57. PLUNGER-TYPE SUPPLY PUMP.



(2) *Operation.*

(a) The plunger follows the camshaft by the force of its plunger spring. As the follower comes off the high point of the cam lobes, the plunger moves toward the retracted position. This plunger movement creates a suction in the pump chamber, causing fuel to enter through the inlet valve

(b) As the cam lobe comes around again, it forces the plunger upward. This forces the fuel out of the chamber through the outlet valve and to the injection pump.

(c) The cam follower drives the plunger through a spring. The spring is calibrated so that it will flex rather than drive the plunger when the pressure in the pump chamber reaches the desired maximum. This effectively regulates pump pressure.

d. *Gear-Type Supply Pump.* The basic overall operation of the gear-type supply pump is the same as the gear-type oil pump.

5. Governors

a. *General.* All diesel engines require governors to prevent overspeeding of the engines under light loads. Automotive diesel engines also demand control of idling speed. Any of the governors provide a variable-speed control which, in addition to controlling minimum and maximum speeds, will maintain any intermediate speed desired by the operator. Engine speed in a diesel is controlled by the amount of fuel injected. The injection, therefore, is designed to supply the maximum amount of fuel that will enable it to operate at full load while reaching a predetermined maximum speed (rpm). If, however, the maximum fuel charge were supplied to the cylinders while the engine was operating under a partial or unloaded condition, the result would be overspeeding and certain engine failure. Thus, it can be seen that the governor must control the amount of fuel injected in order to control the engine speed.

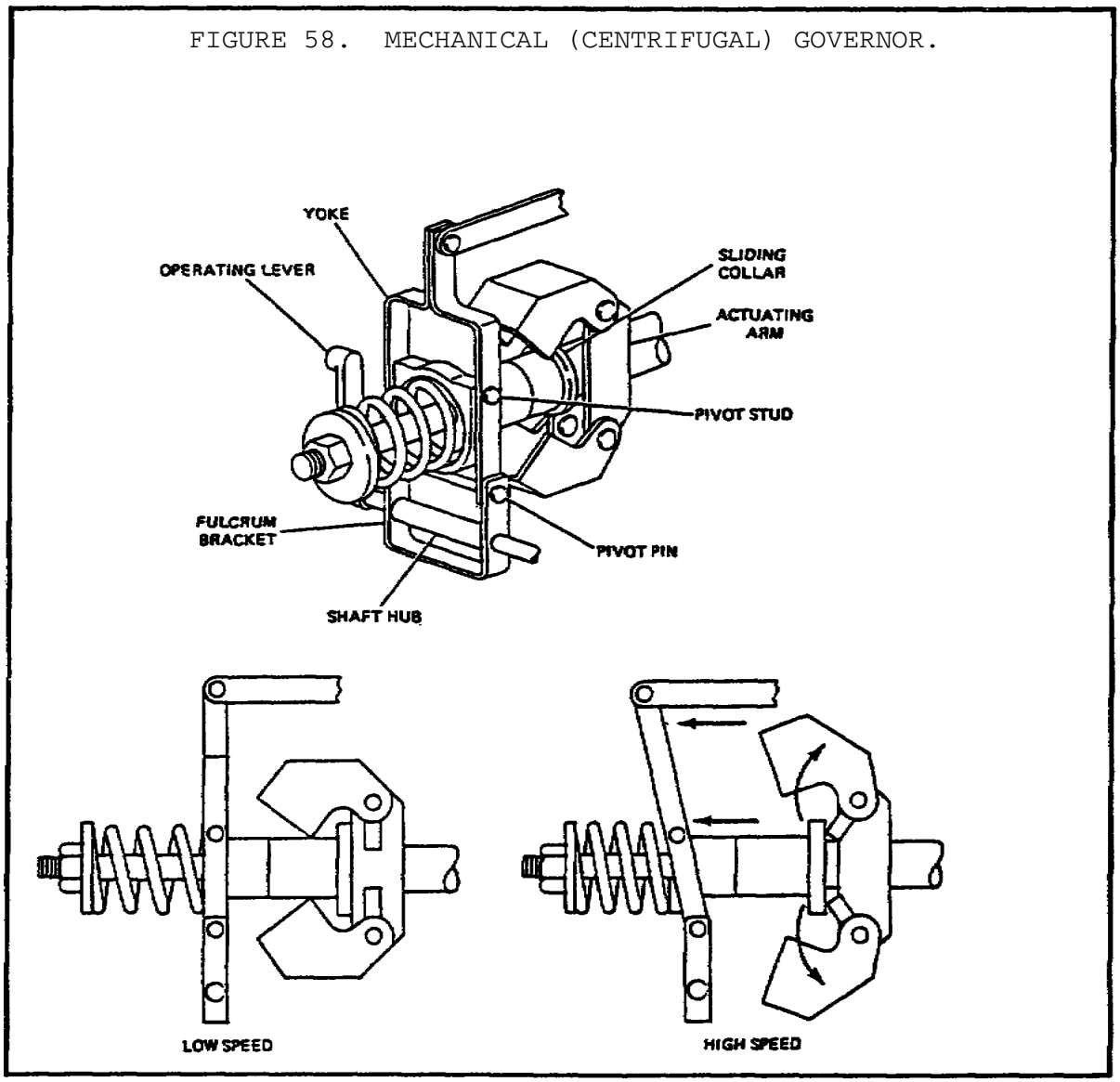
b. *Actuation.* Governors may be actuated through the movement of centrifugal flyweights or by the air-pressure differential produced by a governor valve and venturi assembly.

The centrifugal flyweight type may incorporate a mechanical linkage system to control the injection pump, or it may include a hydraulic system to transmit the action of the weights to the pump. On engines where the rate of acceleration must be high, the governor-controlling weights must be small to obtain the required rapid response from the governor. The problem is that the smaller flyweights will not exert enough force to control the injection pump properly. When this is the case, the flyweights will be used to control a hydraulic relay valve, which, in turn, will control the injection pump through a servo piston.

c. *Mechanical (Centrifugal) Governors* (figure 58).

(1) The operation of the mechanical governor is based on the centrifugal force of rotating weights counterbalanced by springs. When the speed of the engine increases, the weights fly outward, pulling with them suitable linkage to change the setting of the pump control rod. The governor linkage is connected to the injection pump in such a manner that the spring moves the control mechanism toward the full-fuel position. The outward movement of the governor flyweights, through the sliding governor sleeve, will move the pump control rod toward the no-fuel position against the force of the governor spring.

FIGURE 58. MECHANICAL (CENTRIFUGAL) GOVERNOR.



(2) With this type of governor, the operator controls the tension of the governor spring to control the quantity of fuel rather than operating the fuel control rod directly. The fuel delivery control system of the injection pump is connected to the governor yoke in such a manner that any movement of the yoke will directly affect the quantity of the fuel injected. The spring tension is controlled by the operating lever, the movement of which is determined by the position of the foot throttle. The travel of the operating lever is limited by the idle and maximum-speed screws. When the weights are fully collapsed (engine stopped), the spring moves the sliding sleeve and yoke so that the fuel injection pump is in the full-fuel position. When the weights are fully extended, the sliding sleeve and the yoke move to the rear and decrease the amount of fuel delivery.

(3) If the load on the engine is decreased, the engine tends to accelerate, However, when the engine does accelerate, the increased centrifugal force causes the governor flyweights to move outward, resulting in the movement of the fuel control rod through the governor sleeve toward the no-fuel position. This will cause an equilibrium to develop between the flyweights and the governor spring. The movement of the operating lever varies the spring tension. This will cause a change in the point of equilibrium between the spring and the flyweights, effectively changing the engine speed for any given load.

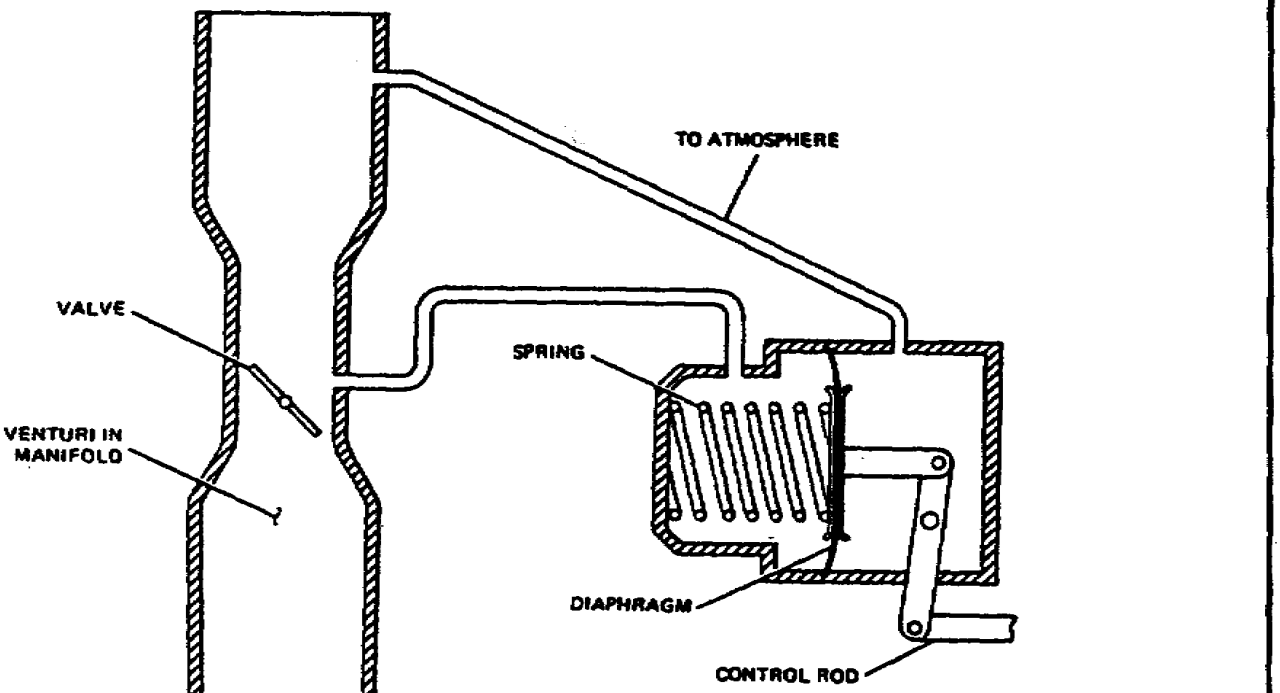
(4) To accelerate the vehicle with a given load, the foot throttle is depressed, which in turn increases the governor spring tension. The increase in tension causes the governor sleeve to move the control rod through the yoke toward the full-fuel position. As engine speed increases, the flyweights will move outward until they reach the point of equilibrium with the governor spring. At this point, engine speed will stabilize.

d. *Vacuum Governor* (figure 59 on the following page).

(1) The vacuum governor operates by employing pressure drop, created by the velocity of the air passing through a venturi located in the air-intake manifold. The governor consists essentially of an atmospheric suspended diaphragm connected by linkage to the control rod of the injection pump.

The chamber on one side of the diaphragm is open to atmosphere, and on the other side it is sealed and connected to the venturi in the manifold. In addition, there is a spring acting on the sealed side of the chamber, which moves the diaphragm and the control rod to the full-fuel position normally.

FIGURE 59. VACUUM-OPERATED GOVERNOR.



(2) When the engine is running, the pressure in the sealed chamber is reduced below the atmospheric pressure existing in the other chamber. The amount of pressure reduction depends on the position of the governor valve and speed of the engine. It is this pressure differential that positions the diaphragm and, consequently, the control rod of the injection pump. The governor valve is controlled by a lever that is connected by suitable linkage to the foot throttle. There is no mechanical connection between the foot throttle and the control rod of the injection pump.

(3) If the engine is operating under load and the speed (rpm) is below governed speed, the velocity of air passing through the venturi is comparatively low and only a slight pressure differential is present. This will cause the spring to move the diaphragm and the injector pump

control rack toward the full-fuel position. As the engine speed picks up, the pressure differential on both sides of the diaphragm and the spring will achieve equilibrium and the position of the control rod will stabilize. The same operating principles will apply in reverse to prevent engine overspeed. As the engine speed increases, the velocity of air through the venturi increases, causing a corresponding increase in the pressure differential on both sides of the diaphragm. The increase in pressure differential causes the diaphragm and the control rod to move against the pressure of the spring toward the no-fuel position. The control rod's position will stabilize when equilibrium is achieved in the diaphragm unit. When the engine is operating at wide-open throttle, the pressure differential is about zero and spring force will move the control rack to the full-fuel position.

(4) For any position of the governor valve between idling and full load of the engine, the diaphragm finds its relative position. Because any movement of the diaphragm also is transmitted to the control rod, the amount of fuel delivery is definitely controlled at all speeds. The diaphragm is moved in the direction of less fuel delivery as the pressure drop between the chambers is increased. The spring will move the control rod in the direction of greater fuel delivery as the pressure drop is decreased.

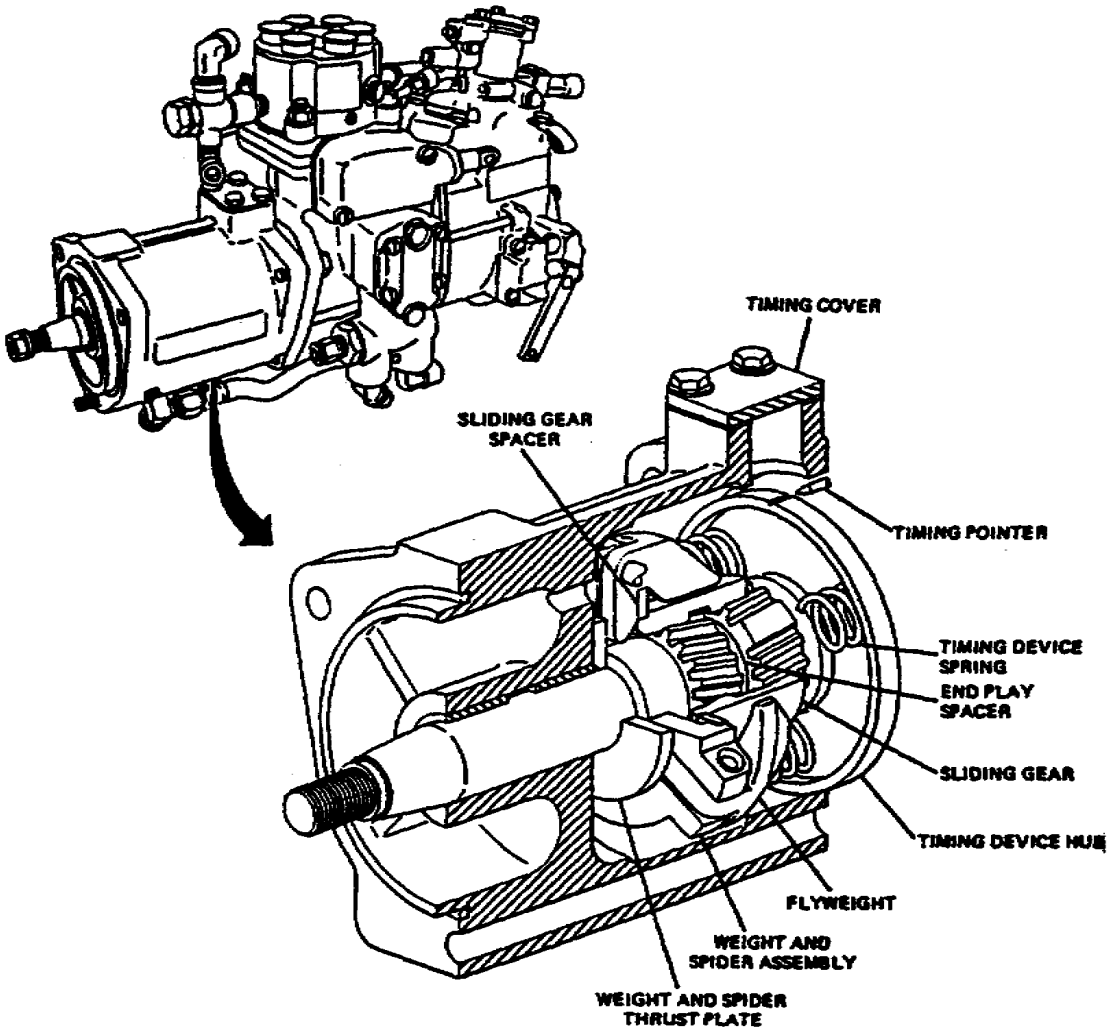
6. Timing Device

a. *General.* A large percentage of fuel injection pumps have timing devices incorporated in them. Varying the time when fuel injection begins will improve diesel engine performance and fuel economy, for the same reason that varying spark timing will improve the performance of a gasoline engine.

b. *Description* (figure 60 on following page).

(1) The timing device usually consists of an aluminum casting with mounting flanges at both ends. A bore in the housing guides and supports the spider assembly. A timing opening, with a cover, is located in the top of the housing and is used to observe the position of the timing pointer in relation to the timing mark on the timing device hub during injection pump timing procedures.

FIGURE 60. TIMING DEVICE.



(2) The timing device hub, with external left-hand helical splines for engaging the internal helical splines of the sliding gear, has a tapered bore and keyway. The hub is secured to the camshaft extension by a woodruff key, nut, and setscrew. The hub is usually counterbored to receive the timing device springs. The springs oppose the flyweight forces of the weight and spider assembly.

(3) The weight and spider assembly has external right-hand helical splines which mesh with the internal helical splines of the sliding gear. The splined end is machined to receive the end play spacer. Three flyweights are pinned to a flange

adjacent to the splines. The weight and spider thrust plate, located between the flange and the timing device housing, carries the back thrust of the flyweights and prevents housing wear.

(4) The sliding gear has internal left-hand helical splines at one end and internal right-hand helical splines at the other, and meshes with the external splines of both the weight and spider assembly and the timing device hub. Correct assembly of the spline train is ensured by a wide land on both the hub and weight and the spider assembly. The sliding gear has a missing tooth on each set of internal splines to receive the wide lands.

Three arms extend from the outer surface of the sliding gear to provide seats for the three timing device springs. The force on these springs is controlled by a sliding gear spacer.

c. *Operation* (figure 61 on the following page).

(1) As the engine rotates the weight and spider assembly, centrifugal force opens the flyweights from their collapsed position against the force of the three timing device springs.

(2) As the flyweights swing out, the sliding gear is forced toward the timing device hub.

(3) The longitudinal movement of the sliding gear on its helical spline causes a slight change in the rotational relationship of the injection pump to the engine, causing injection to begin slightly earlier in the power stroke.

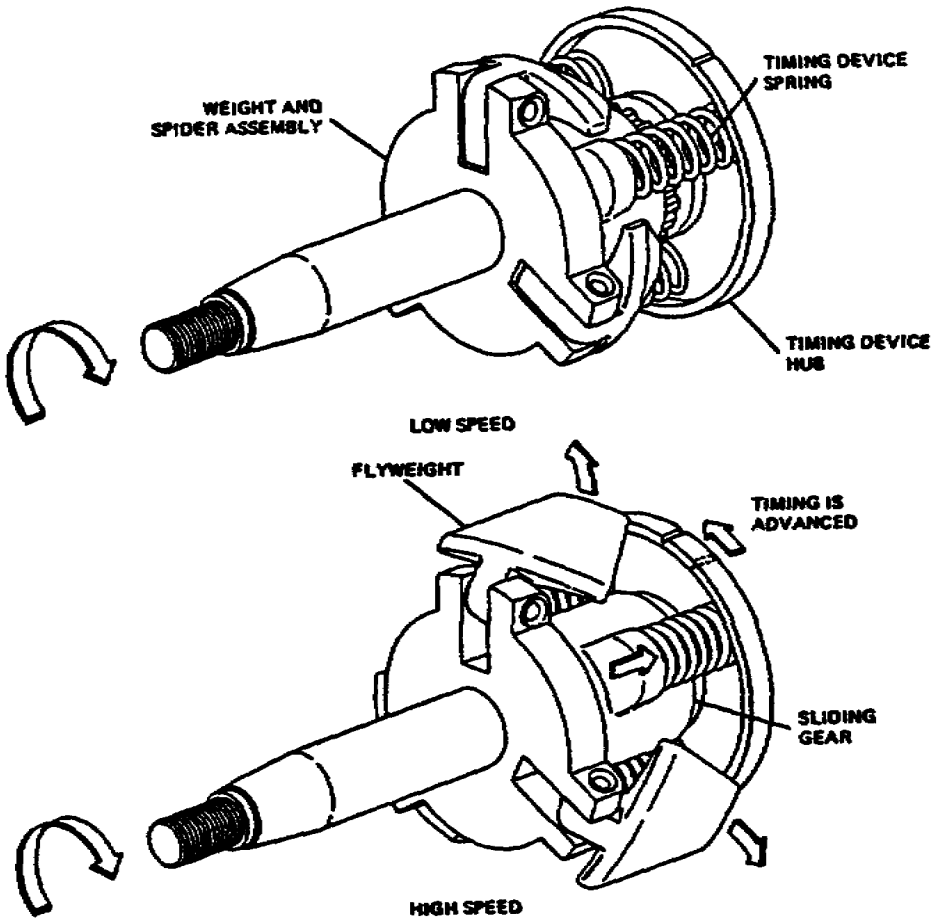
7. Cold Weather Starting Aids

a. *Purpose.* Diesel engines are very difficult to start in cold weather. This is due mainly to the low volatility of the fuel. The two most popular methods of assisting a diesel engine in starting are:

(1) Preheating the induction air in the intake manifold so that adequate vaporization will take place for combustion.

(2) Injecting a fuel into the engine that remains volatile enough in cold weather to initiate combustion.

FIGURE 61. TIMING DEVICE OPERATION.

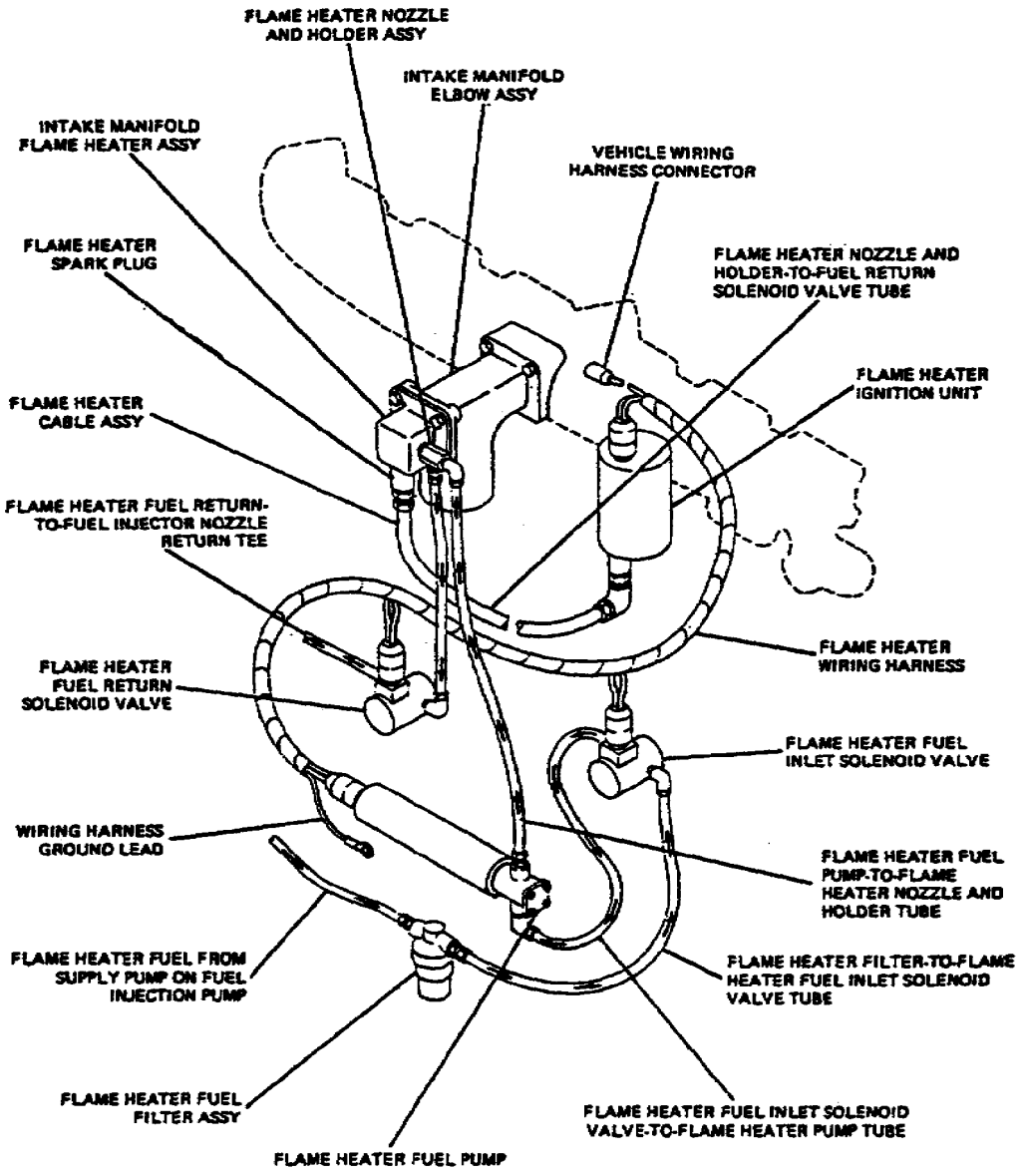


b. *Intake Manifold Flame Heater System* (figure 62 on the following page).

(1) *General.* Engines are equipped with a flame-type manifold heater for heating the induction air during cold weather starting and warmup operations.

(2) Operation. The flame heater assembly is composed of a housing, spark plug, flow control nozzle, and two solenoid control valves. The spark plug is energized by the flame heater ignition unit. The nozzle sprays fuel under pressure into the intake manifold elbow assembly. The fuel vapor is ignited by the spark plug and burns in the intake manifold, heating the air before it enters the combustion chamber.

FIGURE 62. MANIFOLD FLAME HEATER SYSTEM.


FLAME HEATER NOZZLE AND HOLDER ASSY
INTAKE MANIFOLD ELBOW ASSY
INTAKE MANIFOLD FLAME HEATER ASSY
VEHICLE WIRING HARNESS CONNECTOR
FLAME HEATER SPARK PLUG
FLAME HEATER NOZZLE AND HOLDER-TO-FUEL RETURN SOLENOID VALVE TUBE
FLAME HEATER IGNITION UNIT
FLAME HEATER CABLE ASSY
FLAME HEATER FUEL RETURN-TO-FUEL INJECTOR NOZZLE RETURN TEE
FLAME HEATER WIRING HARNESS
FLAME HEATER FUEL RETURN SOLENOID VALVE
FLAME HEATER FUEL INLET SOLENOID VALVE
WIRING HARNESS GROUND LEAD
FLAME HEATER FUEL PUMP-TO-FLAME HEATER NOZZLE AND HOLDER TUBE
FLAME HEATER FUEL FROM SUPPLY PUMP ON FUEL INJECTION PUMP
FLAME HEATER FILTER-TO-FLAME HEATER FUEL INLET SOLENOID VALVE TUBE
FLAME HEATER FUEL FILTER ASSY
FLAME HEATER FUEL INLET SOLENOID VALVE-TO-FLAME HEATER PUMP TUBE
FLAME HEATER FUEL PUMP

(a) Because this system uses fuel from the fuel tank of the vehicle, its components must be compatible with all approved fuels when the system is used with a multifuel engine.

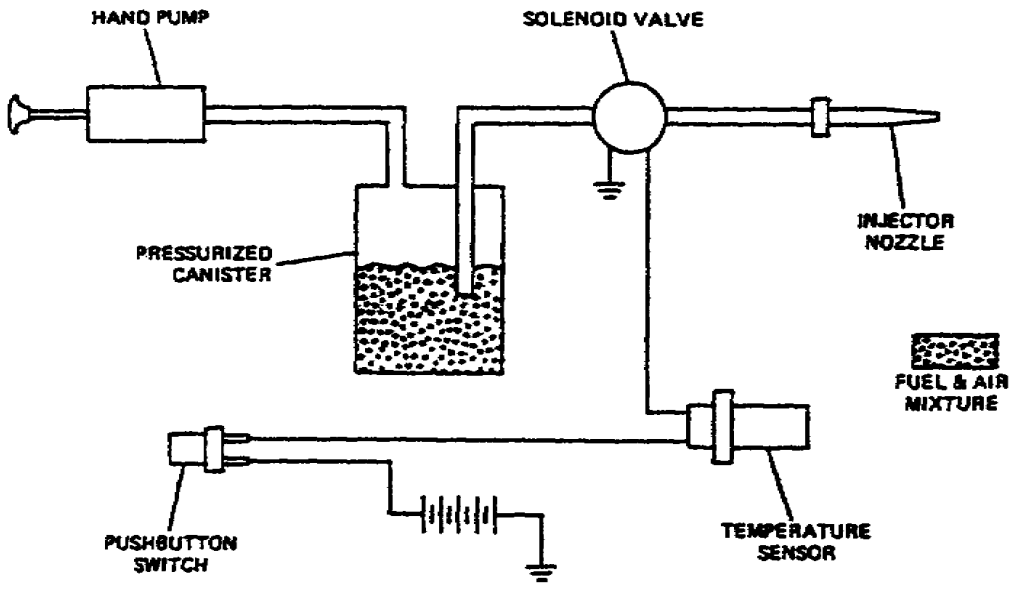
(b) The flame fuel pump assembly is a rotary-type, driven by an enclosed electric motor. The fuel pump receives fuel from the vehicle fuel tank through the vehicle's supply pump and delivers it to the spray nozzle. The pump is energized by an ON-OFF switch located on the instrument panel.

(c) The intake manifold flame heater system has a filter to remove impurities from the fuel before it reaches the nozzle.

(d) Two fuel solenoid valves are used in the flame heater system. The valves are energized (open) whenever the flame heater system is activated. The valves ensure that fuel is delivered only when the system is operating. They stop fuel flow the instant that the engine or the heater system is shut down.

c. *Ether Injection System* (figure 63).

FIGURE 63. ETHER INJECTION SYSTEM.



(1) *General.* The ether injection system assists in the cold weather starting of a diesel engine by injecting ether into the intake manifold. Ether, which is very volatile, will vaporize readily in cold weather, initiating combustion.

(2) *Operation.* A pressurized canister containing ether is fitted to the engine. The flow of ether from the canister to the spray nozzle is controlled by a solenoid valve that closes when it is deenergized. This solenoid is controlled by a pushbutton switch on the instrument panel.

(a) When the switch is pushed, the solenoid is energized. This opens the ether canister. Pressure from the canister pushes ether through a connecting tube to the nozzle, where it discharges into the intake.

(b) The system contains a coolant temperature sensor that will keep the system from functioning when coolant temperature is above 50° F.

8. Fuel Filters

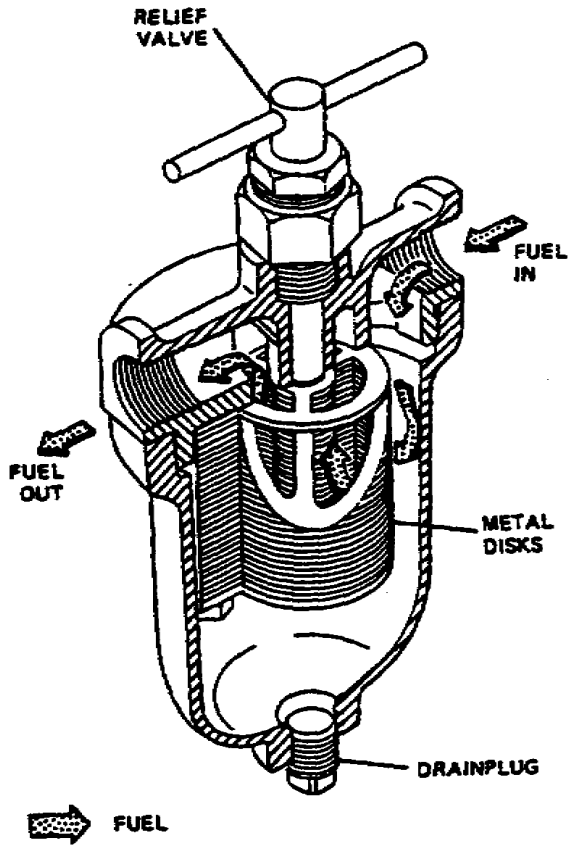
a. *General.* Thorough and careful filtration is especially necessary to keep diesel engines efficient. Diesel fuels are more viscous than gasoline and contain more gums and abrasive particles that may cause premature wear of injection equipment. The abrasives may consist of material that is difficult to eliminate during refining, or they may even enter the tank during careless refueling. Whatever the source, it is imperative that means be provided to protect the system from abrasives.

b. *Configuration.* Most diesel engine designs include at least two filters in the fuel supply systems to protect the closely fitted parts in the pumps and nozzles. The primary filter usually is located between the fuel tank and the fuel supply pump. The primary filter contains a coarse filter medium that removes the larger foreign matter. The secondary filter usually is located between the fuel supply pump and the fuel injection pump. The secondary filter contains a fine filter medium that removes even the most minute traces of foreign matter from the fuel. Additional filtering elements are frequently installed between the injection pump and the nozzle.

c. *Types.* Diesel fuel oil filters are referred to as full-flow filters, because all the fuel must pass through them before reaching the injection pumps. A diesel fuel filter usually incorporates an air valve to release any air that might accumulate in the filter during operation.

(1) *Primary Filters* (figure 64). Metal filters are used as primary filters because the fine particles that will pass through them are not injurious to the supply pump. The filter element is usually of the metal disk type. Solids larger than 0.005 in. remain outside the metal disks, while larger foreign matter and the majority of the water settles to the bottom of the bowl. From here, the foreign matter can be removed through a drainplug. A ball relief valve in the filter cover enables the oil to bypass the filter element if the disks become clogged.

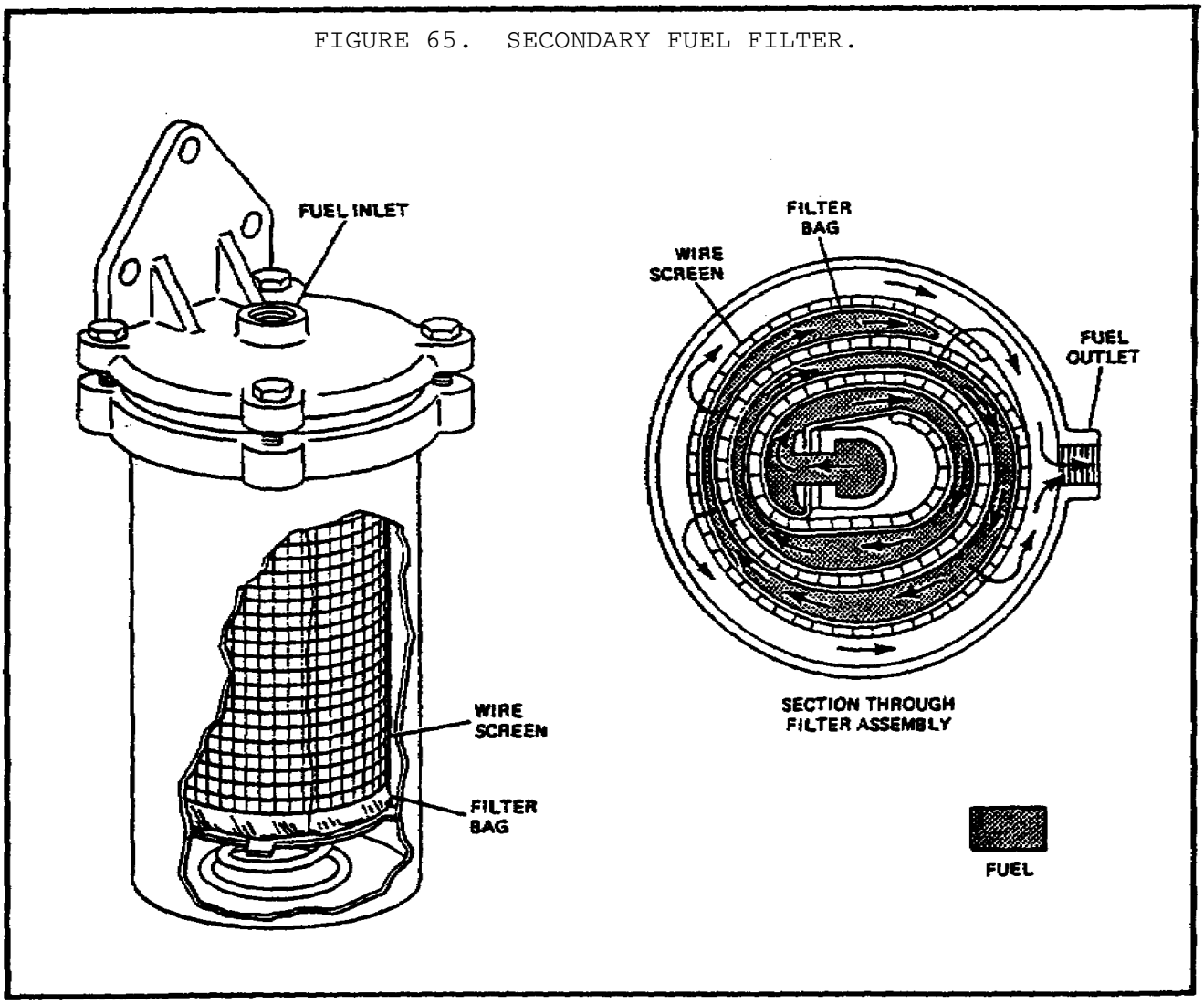
FIGURE 64. PRIMARY FUEL FILTER.



(2) *Secondary Filters* (figure 65 on the following page). Fabric filters, because of their greater filtering qualities, are most commonly used

as main filters for protecting the fuel injection pump. Many of the filters in use are similar to lubricating oil filters. The bag-type filter also is used. The filtering medium is a large bag of close, evenly woven, lintless, acid-resisting textile material. Maximum benefit is derived from the bag's large area by keeping the sides of the bag separated by a wire-screen mat. The screen is the same size as the bag, and the two are fastened detachably to a central feeding spool and wound around it. Layers of bag and screen thus are alternated through the winding, and the entire surface of the bag is available for filtering purposes. The fuel to be filtered flows from the filter inlet at the top, through the spool, and out of the ports to the inside of the bag. The dirt, solids, abrasives, and carbon are caught in the bag, and the clean fuel passes outward and to the filter outlet. The bag may be removed, cleaned, and reinstalled.

FIGURE 65. SECONDARY FUEL FILTER.



9. Engine Retarder System

a. *Purpose.* Engine retarder systems are used on many larger vehicles equipped with diesel engines. They are designed to provide additional stopping ability to a vehicle in motion. These systems also relieve the service brakes of excessive heat buildup and wear due to prolonged application. An auxiliary means of power absorption is used to accomplish the additional braking process. Basically, three different engine retarder systems are currently in use.

b. *Compression Brake.* The compression brake operates by restricting the exhaust gas flowing from the engine. The system basically consists of a butterfly valve fitted into the exhaust pipe between the exhaust manifold and muffler. The system is activated by a switch mounted in the cab. The valve is controlled by an air or vacuum switch mounted on the accelerator pedal. The system operates by restricting the exhaust gases, causing a pressure rise in the exhaust manifold. This pressure increase can vary from 30 to 40 psi. The compression brake causes a pressure buildup in the cylinder during the exhaust stroke. The engine then becomes a low-pressure pump driven by the wheels. This, in turn, slows down or retards the vehicle.

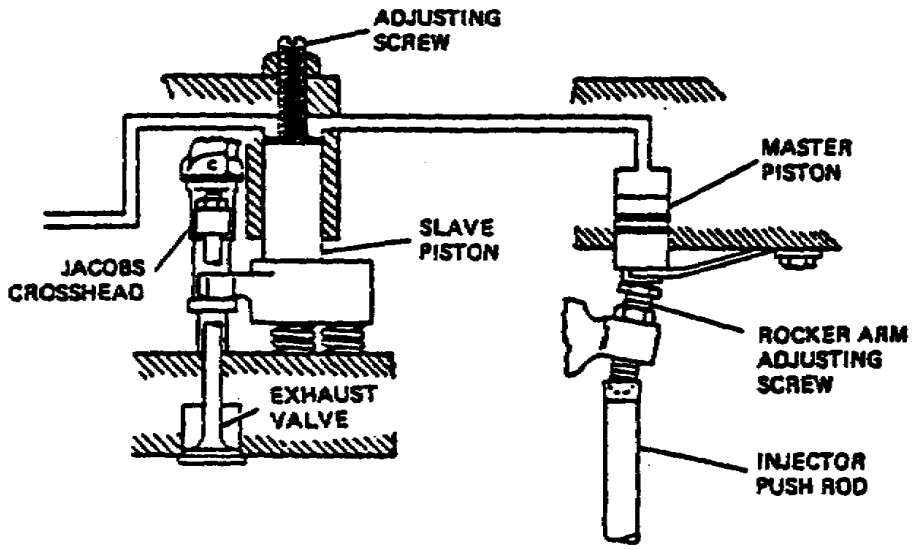
c. *Hydraulic Retarder.* The hydraulic retarder is a pedal-operated unit mounted in the transmission. This system assists the service brakes in controlling the vehicle's speed during long downhill braking or when slowing down in stop and go traffic. The system consists of a retarder cavity located between the converter and transmission housing. The cavity contains a rotor that is connected to the turbine output shaft. Stationary reaction vanes are mounted on both sides of the rotor. When the transmission fluid fills the cavity, it churns against the reaction vanes and slows down the rotor. The retarding efforts are then transmitted to the drive line to slow down the vehicle.

The retarder will continue to operate as long as the retarder pedal is depressed. The rotational energy is transformed into heat energy and absorbed by the transmission fluid. If the retarder is operated continuously, however, the fluid temperature can rise faster than it can be cooled.

Once this happens and the fluid temperature approaches a predetermined level, a warning light on the instrument panel indicates that the retarder operation should be discontinued until the fluid cools down and the warning light goes out. When the retarder pedal is released, the retarder valve closes and the fluid in the cavity automatically discharges and permits the rotor to turn without drag.

d. *Jacobs Engine Brake* (figure 66). The Jacobs engine brake consists of a slave piston mounted over the exhaust valve. The system operates by opening the exhaust valve near the top of the compression stroke. This releases the compressed cylinder charge into the exhaust system. This blowdown of compressed air into the exhaust system prevents the return of energy from the piston on the expansion stroke. The result is an energy loss because the work done in compressing the charge is not returned to usable energy. The system is operated by a three-position switch that allows the driver to select the degree of braking required. The three-position switch is set to allow braking on two, four, or all cylinders. This enables the driver to predetermine how much braking will be needed to stop the vehicle.

FIGURE 66. JACOBS ENGINE BRAKE.



PRACTICAL EXERCISE 2

1. Instructions

On a plain piece of paper, respond to the requirements listed below.

2. First Requirement

Answer these questions regarding the characteristics of diesel fuel.

a. Diesel fuels are considered residue of the refining process. Are the refining specification requirements as exacting as gasoline or less exacting?

b. Foreign material present in diesel fuel can cause damage to finely machined injector parts. Name two ways in which this damage can occur.

c. What is the fluid trait that determines the size of the diesel fuel droplet, which, in turn, governs the atomization and penetration quality of the fuel injector spray?

d. Describe "ignition quality" as it applies to diesel fuel.

e. When a diesel engine produces a noticeable knock during times when the engine is under a light load, this condition is referred to as _____ _____, or _____ _____.

f. Multifuel engines will operate on four groups of fuel, two of which are primary and alternate I fuels. Name the remaining two fuel groups.

g. Before fuel enters the fuel density compensator, it must first pass through a fuel pressure regulator that keeps the fuel at a constant pressure regardless of engine speed or load range. What is this constant pressure (in psi)?

3. Second Requirement

Answer the following questions dealing with the principles, construction, and function of diesel fuel systems.

a. What is the simplest form of diesel combustion chamber design?

b. A precombustion chamber is an auxiliary chamber that is located at the top of the cylinder. How is this chamber normally connected to the main combustion chamber?

c. Prior to actual ignition of the air inside the turbulence chamber, it is estimated that the velocity of the air in the chamber is several times that of crankshaft speed. What is this approximate speed?

d. Name the combustion chamber design that was made specifically for use in the multifuel engine.

e. What are the two methods of injecting fuel into a compression-ignition engine?

f. Name the three basic functions of a diesel injection system.

g. The general operation of a multiple unit injection system is described below. Fill in the blanks.

(1) The fuel supply pump and the fuel filter provide a _____ _____ supply of fuel to the _____ _____ _____ pump. Pressure usually is regulated to approximately _____ psi.

(2) The multiple unit injector contains an _____ _____ pump for each engine cylinder. Fuel is delivered to the _____ at each cylinder from the multiple unit injector in a timed sequence and a _____ amount based on accelerator pedal _____ and _____ _____.

(3) The injectors receive _____ _____ charges from their respective injection pumps and spray it into the _____ _____ in a _____ _____ that is tailored to provide the best overall performance for their particular application.

h. Name the specific type of injection pumps that are arranged in a line so that they may be driven by a common camshaft. The lobes of the camshaft are arranged so that they coincide with the firing order of the engine.

i. What are the names of the two basic groups of spray injector nozzles?

j. The wobble plate pump system is basically the same as the multiple unit injection system. The difference between the two systems lies in the injection pump. Describe what this difference is.

k. A distributor-type injection system uses a fuel metering pump that forces a precisely measured fuel charge into the cup on the intake stroke of the engine. What controls the quantity of this fuel charge?

l. Name the injection system that operates in the same manner as a multiple unit injection system, but rather than using a centrally located unit to house the high-pressure pumps, control racks, pressure regulators, and delivery valves, they are all incorporated into each cylinder.

m. The overall system operation of a pressure-timed injection system is described below. Fill in the blanks.

(1) A _____ _____ with a vented filler cap stores the fuel supply.

(2) Fuel is supplied from the tank to the _____-_____ _____ (_____) pump through the delivery line. An in-line filter is placed in _____ in the line to trap _____ _____ and moisture.

(3) A return line from the PTG pump to the fuel tank is provided to _____ _____ _____ fuel so that operating pressure can be regulated.

(4) The PTG pump delivers _____ _____ of fuel to pressure timed deliver PTD injectors.

(5) Delivery of _____ to the PTD injectors is through a common-rail type _____ line.

(6) A common-rail type return line connects the _____ _____ to the _____ _____ so that excess fuel may be diverted back to the fuel tank.

n. What are the two types of fuel supply pumps?

LESSON 2. PRACTICAL EXERCISE - ANSWERS

1. First Requirement

a. As exacting.

b. (1) Particles of dirt can cause scoring of the injector components

(2) Moisture in the fuel can cause corrosion of the injector components

c. Viscosity.

d. The ignition quality of a fuel is its ability to ignite spontaneously under the conditions existing in the engine cylinder.

e. Ignition delay or ignition lag.

f. (1) Alternate II fuel

(2) Emergency fuel

g. 20 psi.

2. Second Requirement

a. Open chamber.

b. The precombustion chamber is connected to the main combustion chamber by a restricted throat or passage.

c. 50 times the crankshaft speed.

d. Spherical combustion chamber.

e. (1) Air injection

(2) Solid injection

f. (1) To meter the fuel accurately

(2) To distribute the fuel equally to all of the cylinders at a high enough pressure to ensure atomization

(3) To control the start, rate, and duration of the injection

g. (1) low-pressure
multiple unit injection
15

(2) individual injection
injectors
regulated
position
engine speed

(3) fuel charges
combustion chambers
spray pattern

h. Multiple unit injection pump.

i. (1) pintle nozzles

(2) hole nozzles

j. In a wobble plate pump, all of the pump plungers are actuated by a single wobble plate instead of a camshaft that has a separate can for each pump plunger.

k. Speed and load requirements of the engine.

l. Unit injection system.

m. (1) fuel tank

(2) pressure-timed gear (PTG)
series
foreign matter

(3) bleed off excess

(4) controlled amounts

(5) fuel
delivery

(6) PTD injectors
fuel tank

n. (1) Vane-type

(2) Plunger-type

REFERENCES

REFERENCES

The following document was used as resource materials in developing this subcourse:

TM 9-8000